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(A State University Established by the Government of Tamil Nadu)

KARAIKUDI – 630 003

Directorate of Distance Education

M.Sc. (Home Science – Nutrition and Dietetics)

IV - Semester

365 42

FOOD MICROBIOLOGY AND SANITATION

Author

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Units (1-14)

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Phone: 0120-4078900 • Fax: 0120-4078999
Regd. Office: 7361, Ravindra Mansion, Ram Nagar, New Delhi 110 055
• Website: www.vikaspublishing.com • Email: helpline@vikaspublishing.com

Work Order No. AU/DDE/DE1-238/Preparation and Printing of Course Materials/2018 Dated 30.08.2018 Copies - 500

SYLLABI- BOOK MAPPING TABLE

Food Microbiology and Sanitation

SYLLABI	MAPPING IN BOOK
BLOCK-I: FUNDAMENTALS OF MICROBIOLOGY YEAST,MOULDS AND VIRUSES **UNIT - I:** Fundamentals of microbiology- Development of Microbiology- Bacteria- Morphology and cultural characteristics. **UNIT-II:** Yeast- Morphology- Culture- Physiology- Classification - Industrial importance of Yeast. **UNIT-III:** Molds- Morphology- Physiology and Multiplication – Significance of Molds – Common household molds in relation to food science. **UNIT-IV:** Viruses and Bacteriophages – discovery- morphology- Reproduction and its importance.	**Unit –I:** Fundamentals of microbiology **(Pages 1-26);** **Unit- II:** Yeast **(Pages 27-45);** **Unit - III:** Molds **(Pages 46-69);** **Unit - IV:** Viruses and Bacteriophages **(Pages 70- 93)**
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BLOCK-III:MICROBES IN FLESHY FOODS, CANNED FOODS AND FOOD BORNE DISEASES **UNIT -IX:** Microbiology of Fleshy Foods, Poultry and Fish – Contamination, Spoilage, Preservation and Control. **UNIT -X:** Spoilage of Canned Foods. **UNIT-XI:** Food Borne Diseases.	**Unit –IX:** Microbiology of Fleshy Foods (**Pages 137-162)** **Unit- X:** Spoilage of Canned Foods (**Pages 163-182)** **Unit- XI:** Food Borne Diseases (**Pages 183-220)**
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INTRODUCTION

Nowadays, conscious of food quality is expected in all parts of the Globe is very fastly growing. Food quality is given more importance than to flavor and taste. The food is the most affinity medium for any microbes to grow very fastly due to the availability of almost all nutrients in the food required for the microbial growth. The microbial growth may be beneficial or harmful to the consumers. So Intervention in food microbial growth is a challenging tasks to explore the beneficial or harmful to the consumers. So in order to harvest the beneficial effects of microbes, the basic understanding of Food Microbiology and Sanitation is an essential prerequisite in preservation, processing, fermentation, food product preparation and so on. So this book throws open the windows in basic understanding of food microbiology to the students with precise knowledge, clear contents and illustrations in a simple plain language and the presentation of chapters.

This book on Food Microbiology and Sanitation is divided in to four blocks and fourteen units. Block one covers about fundamentals of microbiology, Block two covers contamination, spoilage and preservation of fruits, vegetables and cereal, Block three covers microbes in fleshy foods, canned foods and food borne diseases, Block four covers food safety, packaging and food standards.

This book throws open the eyes of the students to explore the basic understanding of preservation, spoilage and contamination of foods, apart from food safety and sanitation, and food laws and standards. This book is presented with simple, lucid, clear-cut understanding of the syllabus given. I hope this book gives concise bird eye view of understanding the food microbiology and sanitation.

Every unit is detailed with the structure to prepare the student for what to expect in the text. Check Your Progress Questions in between the units helps the students to recollect what had been discussed and Self-Assessment Questions at the end of each unit aids the student to estimate the level of understanding on their own.

Block I – Fundamentals of microbiology- Development of Microbiology- Bacteria- Morphology and cultural characteristics

Overview of microbiology

1.1. Introduction
1.2. Objectives
1.3. Fundamentals of Microbiology
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1.1 INTRODUCTION

The history of microbiology can be traced to 'First Epidemics' on earth, which affected Caveman and were probably waterborne. People had no real understanding of why disease occurred. As the civilization progressed, people started clustering into cities. They increasingly shared communal water, handled unwashed food, and stepped in excrement from casual discharge. The crowding increased and spread water-borne, insect-borne and skin-to-skin infectious diseases. Yet there was no general understanding of why disease occurred. By the 13th century fear of the diseased took a drastic turn in the formation of small leper colonies intended to isolate people carrying the devastating disease caused by Mycobacterium leprae. In 1348, a mass epidemic caused by a single organism, Yersinia pestis, wiped out nearly one third of Europe's population. The Plague spread rapidly in the unsanitary conditions of the Middle Ages, leaving Medieval Europeans defenseless against its devastation. Entire towns succumbed to the disease, leaving the living to dispose of thousands of contaminated corpses. Perhaps the deadliest disease in history, the plague or 'Black Death', claimed over 20 million lives and contributed to the fall of empires.

1.2 OBJECTIVES

After going through this unit, you should be able to:

- Explain and define Fundamentals of Microbiology
- Discuss about Development of Microbiology
- Elaborate upon the concept of Bacteria
- Discuss Haeckel's three - kingdom classification
- Discuss Morphology and cultural characteristics

1.3 INTRODUCTION TO MICROBIOLOGY

As you begin to explore the world of microorganisms, one of the first things you'll notice is their extraordinary diversity – of structure, function, habitat and applications. Microorganisms (or microbes) inhabit every corner of the globe, are indispensable to life on Earth, are responsible for some of the most deadly human diseases and form the basis of many industrial processes. Yet until a few hundred years ago, nobody knew they existed!

1.3.1 What is Microbiology?

Every year thousands of people all over the world fall will after consuming food that seemed absolutely normal but was actually contaminated by harmful organisms. With more people eating away from home, outbreaks of food-borne disease are now becoming more frequent.

To understand the chain of events which precede an outbreak of disease caused by contaminated food, it is necessary to know something about the organisms responsible. These organisms are too small to be seen with the unaided eye and can only be seen under a microscope. That is why they are called microorganisms or microbes and their study is called microbiology.

A compound microscope magnifies a microbe up to 1500 times and an electron microscope up to 5,00,000 times.

The food handler should know that some microorganisms are useful to us and some are harmful causing food spoilage and disease.

Things aren't always the way they seem. On the face of it, 'microbiology' should be an easy word to define: the science (logos) of small (micro) life (bios), or to put it another way, the study of living things so small that they cannot be seen with the naked eye. Bacteria neatly fit this definition, but what about fungi and algae? These two group search contain members that are far from microscopic. On the other hand, certain animals, such as nematode worms, can be microscopic, yet are not considered to be the domain of the microbiologist. Viruses represent another special case; they are most certainly microscopic (indeed, most are submicroscopic), but by most accepted definitions they are not living. Nevertheless, these too fall within the remit of the microbiologist. In the central section of this book you can read about the thorny issue of microbial classification and gain some understanding of just what is and what is not regarded as a microorganism.

Why is microbiology important?

To the lay person, microbiology means the study of sinister, invisible 'bugs' that cause disease. As a subject, it generally only impinges on the popular consciousness in news coverage of the latest 'health scare'. It may come as something of a surprise therefore to learn that the vast majority of microorganisms coexist alongside us without causing any harm. Other microorganisms have been exploited by humans for our own benefit, for instance in the manufacture of anti-biotic and food stuffs. To get some idea of the importance of microbiology in the world today, just consider the following list of some of the general are as in which the expertise of a microbiologist might be used:

- ❖ Medicine
- ❖ Environmental science

- Food and drink production
- Fundamental research
- Agriculture
- Pharmaceutical industry
- Genetic engineering.

The popular perception among the general public, however, remains one of infections and plagues. Think back to the first time you ever heard about microorganisms; almost certainly, it was when you were a child and your parents impressed on you the dangers of 'germs' from dirty hands or eating things after they'd been on the floor. In reality, only a couple of hundred out of the half million or so known bacterial species give rise to infections in humans; these are termed pathogens, and have tended to dominate our view of the microbial world.

In the next few pages we shall review some of the landmark developments in the history of microbiology, and see how the main driving force throughout this time, but particularly in the early days, has been the desire to understand the nature and cause of infectious diseases in humans.

1.3.2 Historical Perspective of Microbiology

The history of microbiology can be traced to 'First Epidemics' on earth, which affected Caveman and were probably waterborne. People had no real understanding of why disease occurred. As the civilization progressed, people started clustering into cities. They increasingly shared communal water, handled unwashed food, and stepped in excrement from casual discharge. The crowding increased and spread water-borne, insect-borne and skin-to-skin infectious diseases. Yet there was no general understanding of why disease occurred. By the 13th century fear of the diseased took a drastic turn in the formation of small leper colonies intended to isolate people carrying the devastating disease caused by Mycobacterium leprae. In 1348, a mass epidemic caused by a single organism, Yersinia pestis, wiped out nearly one third of Europe's population. The Plague spread rapidly in the unsanitary conditions of the Middle Ages, leaving Medieval Europeans defenseless against its devastation. Entire towns succumbed to the disease, leaving the living to dispose of thousands of contaminated corpses. Perhaps the deadliest disease in history, the plague or 'Black Death', claimed over 20 million lives and contributed to the fall of empires.

1.3.3 Bubonic plague

The social and political dislocations as a result of Bubonic plague were immense, and the resulting terror was particularly intense because the cause of the disaster was unknown. Not until 500 years later, in 1890, did microbiologists identify the causative organism, Yersinia pestis, carried by infected fleas. Infection spreads among the rats as fleas bite them. But rats have little resistance to plague and usually die. When rats become scarce, the fleas move to humans and a plague epidemic is under way. Although rare today, Bubonic plague still occurs in parts of the world.

1.3.4 Potato blight

The Irish Famine Potato blight, a disease of plants, rather than humans, caused by a fungus rather than a bacterium, had even greater impact than the plague. Potato blight was responsible for the great Irish famine of the 1800s. Potatoes were the staple of the Irish diet, so when the fungus Phytophthora infestans infected potatoes, causing them to rot in the fields, the result was devastating. By 1846, the potato harvest was so meager that starvation and hunger-based diseases were widespread. An estimated 1,240,000 people had died, and 1,200,000 more had migrated to other countries. Potato blight remains an economic threat to potato farmers even today.

1.3.5 Disease and Warfare

Warfare and infectious diseases have always been intimately connected. The poor sanitation, movement of peoples, and malnutrition that a war brings, all foster outbreaks of disease. For example, in 1812 when Napoleon invaded Russia he lost more of his troops to typhus (a bacterial disease) than to all other causes combined. And more of his soldiers died from wound-related bacterial infections (such as tetanus and gas gangrene) than from the wound itself.

1.3.6 Optical Visual Aids

The first vision aid was invented (inventor unknown- possibly a monk) called a reading stone around 1000 AD. It was a glass sphere that magnified when laid on top of reading materials. In the year 1590, two Dutch eye-glass makers, Zaccharias Janssen and son Hans Janssen experimented with multiple lenses placed in a tube. The Janssens observed that viewed objects in front of the tube appeared greatly enlarged, creating both the forerunner of the compound microscope and the telescope.

1.3.7 Microscopy

Robert Hooke (1635-1703): Robert Hooke, a young English scientist, became the first person to view and describe fungi using a simple compound microscope. In 1665, Hooke published Micrographia, which detailed his observations of tiny cork-like cells resembling ‘little boxes’. Hooke is known principally for his law of elasticity (Hooke's Law) and for his work as ‘the father of microscopy’ - it was Hooke who coined the term ‘cell’ to describe the basic unit of life. Antony van Leeuwenhoek (1632-1723): Antony van Leeuwenhoek, a Dutch merchant, made small hand-held microscopes as a hobby. Squinting through the lens at specimens held on a pin, he discovered a world of invisible creatures he called animalcules (small animals). He found them almost everywhere he looked: in water droplets, particles of soil and his teeth scrapings. In 1674, Leeuwenhoek communicated his discoveries to the Royal Society of London, sending detailed drawings. His primary observations shook the scientific community and led to expanded use of microscopy as a standard scientific tool (Fig. 1.3.1) All his drawings and nine of the estimated 500 microscopes that Leeuwenhoek made still exist. The most powerful of these has a magnification of 266, powerful enough to magnify an average-sized bacterial cell to the size of the period at the end of this sentence.

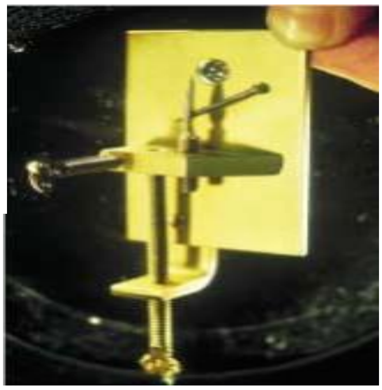


Fig. 1.3.1 Leeuwenhoek's microscope

1.3.8 Spontaneous Generation

The idea that life routinely arises from non-life was supported by Aristotle (Circa 350 BC). According to him, it was: "readily observable that aphids arise from the dew which falls on plants, fleas from putrid matter, mice from dirty hay". This belief remained unchallenged for more than 2000 years. From ancient times, spontaneous generation was thought to be the origin of many organisms (such as rats and flies) that routinely appeared in certain materials. Microorganisms always appeared suddenly in certain materials (meat juices or plant extracts, for example) that had previously been free of them. It seemed logical that microbes were products of spontaneous generation (the formation of living things from inanimate matter).

1.3.9 Needham versus Spallanzani

For 80 years the above debate continued. Then the proponents of spontaneous generation seemed to gain ground when in 1745 an English clergyman named John Needham did a well-publicized experiment. Everyone knew boiling killed microorganisms. Therefore, he boiled chicken broth, put it in a flask, and sealed it. Microorganisms could develop in it only by spontaneous generation. Experiments with gravy seemed to show that life could be generated from non-living materials.

But an Italian priest and professor named Lazzaro Spallanzani was not convinced. According to him, perhaps microorganisms entered the broth after boiling but before sealing. Therefore, Spallanzani put broth in a flask, sealed it, and then boiled it. No microorganisms appeared in the cooled broth. Still the critics were not persuaded. Spallanzani didn't disprove spontaneous generation, they said, he just proved that spontaneous generation required air.

Gradually, spontaneous generation was rejected as the origin of visible organisms. Francesco Redi, a physician in Italy, played a major role. In 1665 he did experiments with covered and uncovered jars of meat. He showed that maggots (fly larvae) developed only in meat that flies could reach to lay eggs on. Apparently, spontaneous generation did not

occur, at least in the case of flies. Instead, flies and by extension all living things come only from preexisting living things. Still, many people believed that microorganisms were an exception to this rule. They are very simple and they always appear, in large numbers, soon after a plant or animal dies. Could decomposition form microorganisms instead of microorganisms causing decomposition? Controversy of spontaneous generation gained momentum during the late 18th and 19th centuries, when further advances in microscopy allowed people to view bacteria and other microorganisms.

1.3.10 Pasteur's Experiments

Remarkably, the controversy continued another 100 years and became a significant barrier to the development of microbiology as a science. Finally, in 1859 the French Academy of Science sponsored a competition to prove or disprove the theory of spontaneous generation of microbes. A young French chemist named Louis Pasteur (1822-1895) entered to counter the argument that air was necessary for spontaneous generation. Pasteur used barriers that allowed free passage of air but not microorganisms. In his most famous experiment, Pasteur boiled meat broth in a flask and then drew out and curved the neck of the flask in a flame in the shape of a swan's neck (Fig. 1.3.2) No microorganisms grew in the flask. But when he tilted the flask so some broth flowed into the curved neck and then tilted it back so the broth was returned to the base of the flask, the broth quickly became cloudy with the growth of microbial cells. Gravity had caused the microbial cells that had entered the flask to settle at the low point of the neck. They never reached the broth in the base until they were washed into it. Thus, Pasteur convinced the scientific world that spontaneous generation of microorganisms does not occur even in the presence of air. Pasteur's simple but elegant experiments grounded microbiology in scientific reality. Microorganisms could now be studied by rational scientific means. Probably the most famous contribution to microbiology by Pasteur is the heating process he developed to kill spoilage microbes while still preserving flavor.

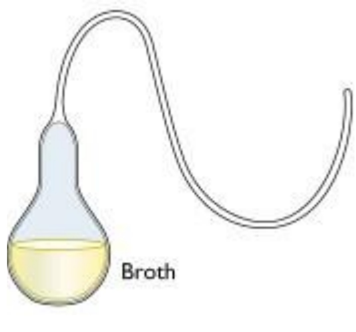


Fig. 1.3.2 Pasteur's swan-neck flask

1.3.11 Fermentation

Another important contribution of Pasteur was defining fermentation. In 1856, the father of one of Pasteur's chemistry students asked him to help him solve some problems he was encountering in his attempt to make alcohol by fermenting beetroot. Often, instead of alcohol,

the fermentations yielded lactic acid. At the time, fermentation was believed to be a pure chemical process in which sugar was transformed into alcohol. But in 1857, Pasteur proved that a microscopic plant caused the souring of milk (lactic acid fermentation). Pasteur was able to prove that living cells, the yeast, were responsible for forming alcohol from sugar, and that contaminating microorganisms found in ordinary air could turn the ferments sour. Next, he identified the microorganisms responsible for both normal and abnormal fermentations, and found that through heating wine, beer, milk, or vinegar briefly, certain living organisms could be killed, thereby sterilizing or 'pasteurizing' the substances. He reported his findings in "MÃ©moire sur la fermentation appelÃ©e lactique" (Memoir on the fermentation of lactic acid) in 1857, and "MÃ©moire sur la fermentation alcoholique" (Memoir on the fermentation of alcohol) in 1860. Pasteur also made notable contributions in the field of vaccination and immunity. Studying cholera, Pasteur found that attenuated organisms, inoculated into poultry, offered protection against virulent strains. Based on this research, he developed the first rabies and anthrax vaccines.

1.3.12 Immunology

Edward Anthony Jenner (1749-1823) was an English scientist who studied his natural surroundings in Berkeley, Gloucestershire. Jenner is widely credited as the pioneer of smallpox vaccine, and is sometimes referred to as the 'Father of Immunology'. Though Pasteur's achievements in microbial immunity were revolutionary, Jenner is credited with inventing the first vaccine against smallpox in late 1700s. In 1796, Jenner developed a controversial experiment to determine the validity of rumours that were circulating in rural communities. Milkmaids and villagers often recanted, "if you want to marry a woman who will never be scarred by the pox, marry a milkmaid." Jenner speculated that becoming infected with cowpox could offer protection against the more virulent smallpox. To test his hypothesis, he created an inoculation with scrapings of cowpox lesions from the fingers of Sarah Nelmes, a young milkmaid and injected it into an 8-year old boy named James Phipps. As expected, James developed the mild fever and cowpox lesions typical of the disease. After a few weeks of recovery, Jenner injected James with the live smallpox virus and found that the boy was indeed protected from the disease. In 1798, Jenner published his findings and presented them to the Royal Society.

1.3.13 Germ Theory of Disease

Once spontaneous generation of microbes was disproved, microbiology exploded. It changed from an observational science to an experimental science. The way was opened to study the cause of infectious diseases. Building on Pasteur’s work, a German physician, Robert Koch, proved that microorganisms (germs, as they were and are still sometimes called) cause disease. He showed further that specific microorganisms cause specific diseases. Koch also introduced higher scientific standards of rigor to microbiology, as exemplified by those called Koch’s postulates.

1.3.14 Koch’s postulates

In 1876 Robert Koch while studying anthrax, a disease of cattle and sheep that also affects humans established “scientific rules” to show a cause and effect relationship between a microbe and a disease known as Koch’r postulates as follows:

- The same organisms must be found in all cases of a given disease. The organism must be isolated and grown in pure culture.
- The isolated organism must reproduce the same disease when inoculated into a healthy susceptible animal.
- The original organism must again be isolated from the experimentally infected animal.

During his work on anthrax, Koch made another critically important contribution to microbiology. He developed a technique to obtain a pure culture of a bacterium (one that contains only a single kind of bacteria) and propagate it. In nature many kinds of bacteria are found growing together (mixed cultures). It is difficult to do valid experiments using mixed cultures because they are so complicated, although such studies are now becoming more common.

1.3.15 Antiseptic Surgery

Joseph Lister (1827-1912), a British surgeon was the pioneer of antiseptic surgery, who promoted the idea of sterile surgery while working at the Glasgow Royal Infirmary. Lister successfully introduced carbolic acid to sterilise surgical instruments and to clean wounds, which led to reduced post-operative infections and made surgery safer for patients.

1.3.16 Sterilization

In 1877, John Tyndall published his method for fractional sterilization and clarified the role of heat resistant factors (spores) in putrefaction. Tyndall's conclusion added a final footnote to the work of Pasteur and others in proving that spontaneous generation is impossible. For some of his experiments on light and gases he needed to cleanse the air of particles and so developed a completely novel way to assay the purity of air. ‘The eye being kept sensitive by darkness’, Tyndall reported, ‘a concentrated beam of light was found to be a most searching test for suspended matter – a test indeed indefinitely more searching than that furnished by the most powerful microscope’. Using his new piece of equipment, which relied on observing light scattered by dust particles, Tyndall quickly made a series of important observations on the properties of the ‘floating matter’ of air.

1.3.17 Milk Fermentation

In 1878, Joseph Lister published his study of lactic fermentation of milk, demonstrating the specific cause of milk souring. His research was conducted using the first method developed for isolating a pure culture of a bacterium, which he named Bacterium lactis.

1.3.18 Virology

Virology, the study of viruses, began in 1892, when the Russian microbiologist Dmitri Iwanowski discovered the tobacco mosaic virus. Iwanowski was studying a disease of tobacco plants called tobacco mosaic disease. To identify its cause, he forced juice from diseased plants through filters that retained the smallest bacteria. He found the filtered juice still caused disease. Because bacteria were believed to be the smallest microorganisms, Iwanowski first thought his methodology might be

flawed. But repeated experimentation convinced him that minute disease-causing agents were passing through the filter. He called these tiny agents 'filterable viruses'. They could not be seen, even under the most powerful microscopes of that time. Until the electron microscope was developed in the 1930s, we knew viruses existed.

1.3.19 Bacteriophage

In 1915, the first discovery of bacteriophage was done by Frederick Twort. Twort's discovery was something of an accident. He had spent several years growing viruses and noticed that the bacteria infecting his plates became transparent. Later on in 1917 Felix d'Herrelle independently described bacterial viruses and coined the name 'bacteriophage'. In 1926, Thomas Rivers distinguished between bacteria and viruses, establishing virology as a separate area of study.

Check your progress - 1
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit
1. What is food microbiology? What areas does it cover?

1. What is food microbiology? What areas does it cover?

Microorganisms (or microbes) inhabit every corner of the globe, are indispensable to life on Earth, are responsible for some of the most deadly human diseases and form the basis of many industrial processes.

Every year thousands of people all over the world fall will after consuming food that seemed absolutely normal but was actually contaminated by harmful organisms. With more people eating away from home, outbreaks of food-borne disease are now becoming more frequent.

To understand the chain of events which precede an outbreak of disease caused by contaminated food, it is necessary to know something about the organisms responsible. These organisms are too small to be seen with the unaided eye and can only be seen under a microscope. That is why they are called microorganisms or microbes and their study is called microbiology.

A compound microscope magnifies a microbe up to 1500 times and an electron microscope up to 5,00,000 times.

The food handler should know that some microorganisms are useful to us and some are harmful causing food spoilage and disease.

1.4 DEVELOPMENT OF MICROBIOLOGY

The development of microbiology. In the late 1800s and for the first decade of the 1900s, scientists seized the opportunity to further develop the germ theory of disease as enunciated by Pasteur and proved by Koch. There emerged a Golden Age of Microbiology during which many agents of different infectious diseases were identified. Many of the etiologic agents of microbial disease were discovered during that period,

leading to the ability to halt epidemics by interrupting the spread of microorganisms.

Despite the advances in microbiology, it was rarely possible to render life- saving therapy to an infected patient. Then, after World War II, the antibiotics were introduced to medicine. The incidence of pneumonia, tuberculosis, meningitis, syphilis, and many other diseases declined with the use of antibiotics.

Modern microbiology. Modern microbiology reaches into many fields of human endeavor, including the development of pharmaceutical products, the use of quality- control methods in food and dairy product production, the control of disease- causing microorganisms in consumable waters, and the industrial applications of microorganisms. Microorganisms are used to produce vitamins, amino acids, enzymes, and growth supplements. They manufacture many foods, including fermented dairy products (sour cream, yogurt, and buttermilk), as well as other fermented foods such as pickles, sauerkraut, breads, and alcoholic beverages.

One of the major areas of applied microbiology is biotechnology. In this discipline, microorganisms are used as living factories to produce pharmaceuticals that otherwise could not be manufactured. These substances include the human hormone insulin, the antiviral substance interferon, numerous blood- clotting factors and clot dissolving enzymes, and a number of vaccines. Bacteria can be reengineered to increase plant resistance to insects and frost, and biotechnology will represent a major application of microorganisms in the next century.

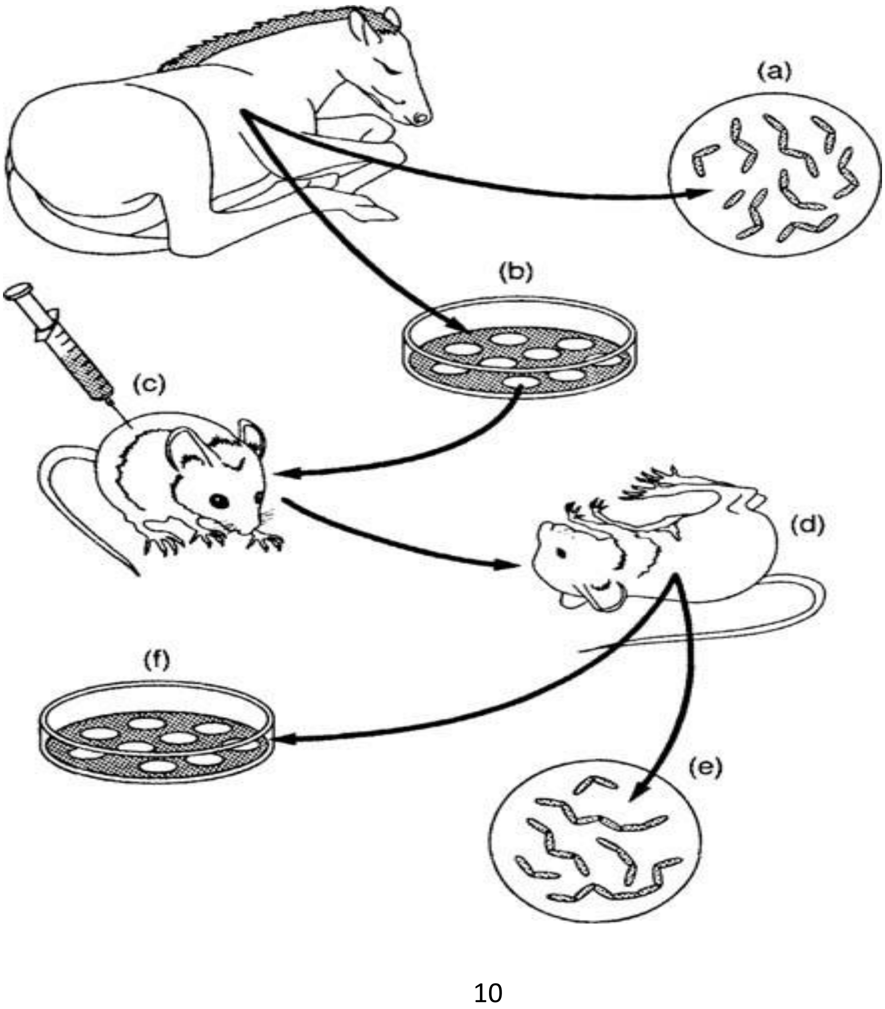


Fig.

1.4.1 The steps of Koch's postulates

The steps of Koch's postulates used to relate a specific microorganism to a specific disease. (a) Microorganisms are observed in a sick animal and (b) cultivated in the lab. (c) The organisms are injected into a healthy animal, and (d) the animal develops the disease. (e) The organisms are observed in the sick animal and (f) reisolated in the lab.

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Work with viruses could not be effectively performed until instruments were developed to help scientists see these disease agents. In the 1940s, the electron microscope was developed and perfected. In that decade, cultivation methods for viruses were also introduced, and the knowledge of viruses developed rapidly. With the development of vaccines in the 1950s and 1960s, such viral diseases as polio, measles, mumps, and rubella came under control.

1.4.1. Growth Phases

1. The initial phase is called the lag phase during which there is no growth. The number of bacteria remains constant and the cells get adjusted to their new environment. Bacteria show an increase in size but not in number.
2. In the exponential growth phase or logarithmic growth phase, the rate of growth increases at a very rapid or logarithmic pace. In this phase the generation time is constant and the growth rate is the highest.
3. In the stationary phase the rate of multiplication decreases gradually and average generation time increases. During this phase the number of living bacteria remains constant due to the death of some bacteria and the rate of growth equals the rate of death. They may die from lack of nourishment.
4. In the death phase the number of living bacteria declines rapidly at the same rate at which they grew. The number of surviving cells taper off very gradually. The more vulnerable cells die first and the resistant forms remain for some months or even years. They die because of a change in the environment such as (a) exhaustion of nutrients, (b) accumulation of toxic metabolic waste products, or (c) alteration of pH, etc.

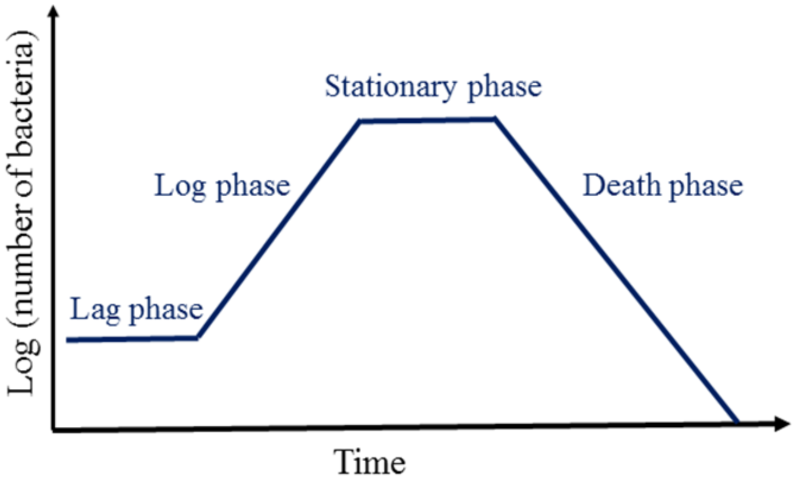


Fig. 1.4.1.1. Four Phases of microbial Growth

True growth is defined as an orderly increase in all cell constituents. However, microbial growth is measured in terms of increase in cell number.

Many common methods of preserving food and keeping it fit for consumption depend not on I he destruction or removal of microorganisms but on (a) delay in the initiation of growth and (b) hindrance to growth once it has begun.

Most microorganisms, when added to food, multiply at a very rapid rate under favourable c onditions. A single bacterial cell divides into two every 20 to 30 minutes. If the rate of multiplication is maintained, a single cell will produce one billion new cells after a period of 10 hours.

1.4.2 Food, Industrial and Environmental Microbiology

1) Food Microbiology

Food microbiology encompasses the study of microorganisms which have both beneficial and deleterious effects on the quality and safety of foods. It focuses on the general biology of the microorganisms that are found in foods including: their growth characteristics, identification, and pathogenesis. Specifically, areas of interest which concern food microbiology are: food poisoning, food spoilage and food legislation. Pathogens in product, or harmful microorganisms, result in major public health problems worldwide and are the leading causes of illnesses and death. In the United States alone, food borne illness has been estimated to cause 5,000 deaths and 76 million illnesses per year.

2) Factors affecting Microbial Growth in Food

There are broadly two types of factors that affect the growth of microorganisms in food products: intrinsic and extrinsic. The intrinsic parameters are properties that exist as part of the food product itself such as pH, moisture content (water activity), Oxidation-reduction potential, nutrient content, antimicrobial constituents and biological structures of food. On the other hand, extrinsic parameters are those properties of the environment (processing and storage) that exist outside of the food product and, may affect both the foods and their microorganisms. These include storage temperature of food, relative humidity, presence/concentration of gases and presence/activities of other microorganisms.

3) Sources of Microorganisms in Food

Bacteria can be found virtually everywhere including humans and can enter food products through different routes. Some of the most

common ways in which microorganisms enter food products are as follows:

- Soil, water, and in-plant environment
- Animal feeds
- Animal hides Gastrointestinal tract
- Food handlers
- Food Utensils
- Air and dust
- Vegetables (plant) and vegetable products
- Globalization of food supply
- Terrorist attacks

4) Foodborne Illness

Microorganisms can cause a variety of effects in food products including spoilage, which primarily affects product quality, and food poisoning, which is generally caused by pathogens. A foodborne illness (or disease) is exactly what the term indicates - a disease or illness caused by the consumption of contaminated foods or beverages. Foodborne diseases are primarily of two primary types: food-borne infections and food intoxications. While the former takes place due to ingestion of microbes, followed by growth, tissue invasion, and/or release of toxins, the latter is caused as a result of ingestion of toxins in foods in which microbes have grown. More than 250 different foodborne diseases have been described. Most of these diseases are infections, caused by a variety of bacteria, viruses, and parasites. Other diseases are poisonings, caused by harmful toxins or chemicals that have contaminated the food, for example, poisonous mushrooms or heavy metal contamination.

1.4.3 Food Spoilage

Spoilage organisms alter food which results in changes in texture, appearance and organoleptic qualities of the food, making it unsuitable for human consumption. Spoilage is often the result of a succession. One organism creates an environment conducive to the growth of another. Common microbial food spoilage are:

I. Putrefaction- Protein + proteolytic micro organism’s — amino acids + amines + ammonia + H2S
II. Fermentation- Carbohydrates + fermenting microrganism’s —acids + alcohols + gases
III. Rancidity- Fatty foods + lypolytic micro organism’s — fatty acids + glycerol

1.4.4 Fermented Foods

These are the foods that have been subjected to the action of micro-organisms or enzymes, in order to bring about a desirable change. Numerous food products owe their production and characteristics to the fermentative activities of microorganisms. Fermented foods originated many thousands of years ago when presumably microorganism contaminated local foods. Fermentation is most common method of preservation. Furthermore, microbial fermentation can increase nutritional quality and digestibility of food while producing desirable textures and flavours (organoleptic properties). Fermentation, like spoilage, is

dependent on microbial succession. The physical and chemical nature of the food determines fermentation organisms and inhibits unwanted microbes. Microbes involved are lactobacilli (lactic acid bacteria), acetic acid bacteria, yeasts and occasionally mycelial fungi. Early procedures used 'backslop' method. They retained some material from a previous fermentation and added it to a fresh batch of ingredients. Today, "starter cultures (collection of well identified and characterized microorganisms which initiate fermentation) are extensively used in the dairy industry. Some examples of fermented foods are as follows:

- Dairy Products- Buttermilk, Sour cream, Yoghurt, Cheese
- Meat Products: Many European sausages, Cured ham, Salami
- Fish products: Mainly Far East
- Vegetables and Cereal Fermentation Products: Wine, Bread, Sourdough, Tofu, Pickles, Silages

1.4.5 Food Preservation

It is the process of treating and handling food to stop or greatly slow down spoilage (loss of quality, edibility or nutritive value) caused or accelerated by microorganisms. Some methods, however, use benign bacteria, yeasts or fungi to add specific qualities and to preserve food (e.g., cheese, wine). Maintaining or creating nutritional value, texture and flavour is important in preserving its value as food. Preservation usually involves preventing the growth of bacteria, fungi, and other microorganisms, as well as retarding the oxidation of fats which cause rancidity. It also includes processes to inhibit natural ageing and discolouration that can occur during food preparation such as the enzymatic browning reaction in apples after they are cut. Some preservation methods require the food to be sealed after treatment to prevent recontamination with microbes; others, such as drying, allow food to be stored without any special containment for long periods.

1.4.6 Industrial Microbiology

Humans use the versatility of microbes to make improvements in industrial production, agriculture, medicine, and environmental protection. Use of microorganisms, usually grown on a large scale, to obtain valuable commercial products by way of significant chemical transformations is called industrial microbiology. This discipline of microbiology dates back and originated with beat and wine making fermentation processes (alcoholic fermentation) and subsequently expanded in the area of production of pharmaceuticals (e.g. antibiotics), food additives (e.g. amino acids), organic acids (e.g. butyric acid and citric acid), enzymes (e.g. amylases, proteases), and vitamins. All these products are obtained by enhancing the metabolic reactions that microorganisms were already capable of carrying out in natural conditions. But, at present, in addition to this traditional industrial microbiology, a new era of microbial biotechnology is rapidly expanding in which the genes of the microorganisms responsible for such and other metabolic reactions are being manipulated to give to many new products at commercial level.

1.4.7 Fermentation in Industry

In industry, as well as other areas, the uses of fermentation progressed rapidly after Pasteur's discoveries. Between 1900 and 1930, ethyl alcohol and butyl alcohol were the most important industrial

fermentations in the world. But by the 1960s, chemical synthesis of alcohols and other solvents were less expensive and interest in fermentations waned. Interest in microbial fermentations is experiencing a renaissance. Plant starch, cellulose from agricultural waste, and whey from cheese manufacture are abundant and renewable sources of fermentable carbohydrates. Additionally, these materials, not utilized, represent solid waste that must be buried in dumps or treated with waste water (Fig. 2.1).

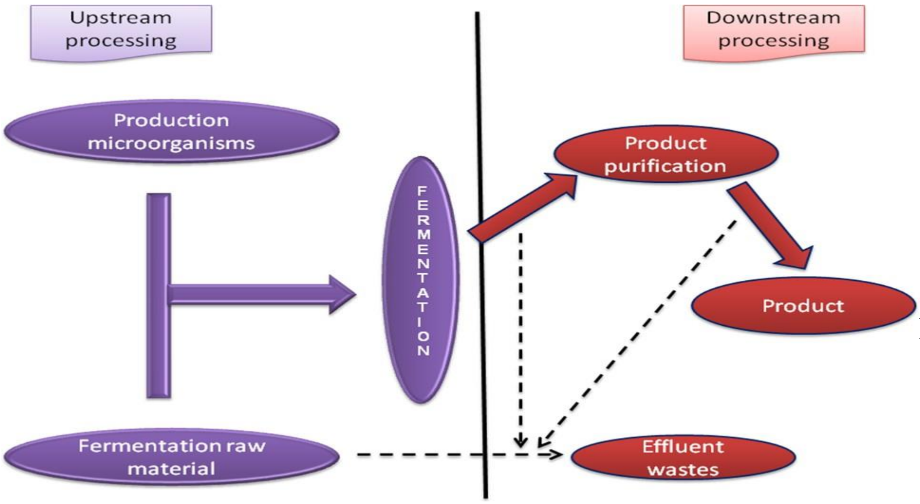


Fig. 1.4.2 Industrial microbiology

1.4.8 Major products of industrial microbiology

The major products of industrial microbiology can be enlisted as follows: Food and beverage biotechnology - fermented foods, alcoholic beverages (beer, wine) and flavors Enzyme technology - production and application of enzymes Metabolites from microorganisms - amino acids, antibiotics, vaccines, biopharmaceuticals, bacterial polysaccharides and polyesters, specialty chemicals for organic synthesis (chiral synthons) Biological fuel generation - ethanol or methane from biomass, single cell protein, production of biomass, microbial recovery of petroleum Environmental biotechnology - water and wastewater treatment, composting (and landfilling) of solid waste, biodegradation/bioremediation of toxic chemicals and hazardous waste Agricultural biotechnology - soil fertility, microbial insecticides, plant cloning technologies Diagnostic tools - testing & diagnosis for clinical, food, environmental, agricultural applications, biosensors.

1.4.9 Environmental Microbiology

Environmental microbiology is the study of the composition and physiology of microbial communities in the environment. The environment in this case means the soil, water, air and sediments covering the planet and can also include the animals and plants that inhabit these areas. Environmental microbiology also includes the study of microorganisms that exist in artificial environments such as bioreactors. Microbial life is amazingly diverse and microorganisms literally cover the planet. It is estimated that we know less than 1% of the microbial species on Earth. Microorganisms can survive in some of the most extreme environments on the planet and some can survive high temperatures, often above 100°C, as

found in geysers, black smokers, and oil wells. Some are found in very cold habitats and others in highly salt / saline, acidic, or alkaline water.

1.4.10 Soil Microbiology

Soil is the top layer of the Earth's lithosphere, formed from weathered rock that has been transformed by living organisms. Soil is composed of mineral and organic solid particles, air, soil solution, and living organisms which occur in this edaphon. The organisms living in soil create a community called the edaphon. These are bacteria, fungi, unicellular algae, vascular plants and animals especially invertebrates that occur in the surface layer of soil. Due to the variety of their metabolic abilities the soil microorganisms ensure the permanence (continuity) of element cycles in nature. The effect of their activities is not only the mineralization of organic compounds but also the changes of mineral compounds, which have a big impact upon the development of the green plants. Edaphon constitutes about 1-10% of the dry mass of the soil organic matter. Both bacteria and fungi are the co-creators of soil's structure as they create humus - the most important component of soil that greatly influences its structure, sorption qualities and the richness in organic compounds. They have a great effect on the way of creation of crumb texture and a spongy structure of soil by producing mucous capsules, and like the filamentous bacteria and the fungi by their form of growth.

1.4.11 Water Microbiology

The biotopes of water microorganisms may be underground and/ or surface waters as well as bottom sediments. The underground waters (mineral and thermal springs, ground waters) - due to their oligotrophic character (nutrient - deficient) are usually inhabited by a sparse microflora that is represented by a low number of species with almost a complete lack of higher plants or animals. The surface waters such as streams, rivers, lakes and sea waters are inhabited by a diverse flora and fauna. Microorganisms in those waters are a largely varied group. Next to the typical water species, other microorganisms from soil habitats and sewage derived from living and industrial pollution occur. Bottom sediments are a transient type of habitat i.e. the soil-water habitat that is almost always typically oxygen-free in which the processes of anaerobic decomposition by microorganisms cause the release of hydrogen sulphide and methane into water. In the bottom sediment, anaerobic putrefying microflora, cellulolytic bacteria and the anaerobic chemoautotrophs develop.

1.4.12 Air Microbiology

Air is an unfavorable environment for microorganisms, in which they cannot grow or divide. It is merely a place which they temporarily occupy and use for movement. Therefore, there are no metabolic connections occurring between different microorganisms in air (such as in soil or water). As a result they form only a random collection of microorganisms. Microorganisms get into air as a consequence of wind movement, which sweeps them away from various habitats and surroundings (soil, water, waste, plant surfaces, animals, and other), or are introduced during the processes of sneezing, coughing, or sewage aeration. Air conditions are unfavorable for the microorganisms due to a lack of adequate nutrients, frequent deficit of water, threat of desiccation, and solar radiation. There are 3 main groups of microorganisms that occur in air: viruses, bacteria and fungi. Bacteria may exist as vegetative or resting

forms, however fungi occur in the form of spores or fragments of mycelium.

- ❖ Amount of emitted microorganisms, depending on the emitter
- ❖ Distance from the source of emission
- ❖ Wind speed
- ❖ Microorganisms survival rate, depending on the factors discussed above Precipitation.

Check your progress - 2
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.
1. Discuss Growth and development of microbiology?
2. Explain the factors affecting the microbial growth in food?
3. Write a short note on Food Preservation.

2. Growth and development of microbiology?

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1.3 BACTERIA

Bacteria are found everywhere — in and on soil, water, air, plants, animals, humans and their food. Bacteria are both useful and harmful to humans. They are capable of fermenting sugar to lactic acid. This makes them important in the manufacture of dairy products like curds, yoghurt, buttermilk and cheese, and fermented vegetable products like sauerkraut and dill pickles.

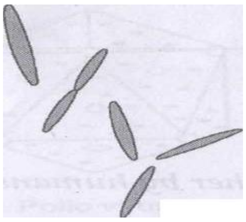
Some bacteria can oxidise ethyl alcohol to acetic acid and are necessary for the manufacture of vinegar. They leaven idli, dosa and dhokla batters and develop desirable flavours in them.

They help in fermenting and curing coffee and cocoa beans and in the production of enzymes, acids and other substances like glutamate and certain stabilisers added to food.

Many bacteria are pathogenic to humans and animals. Most food infections and food poisonings, ire of bacterial origin. They are also responsible for spoilage of food.

Canned foods, fruit juices and alcoholic beverages are spoiled by acid producing bacteria. They spoil beverages and milk by forming rope or slime in them. They may cause surface discoloration on many foods or putrefy foods accompanied with the development of a foul smell.

Shape and Size Bacteria are minute, unicellular organisms of variable shape and activity. They tire so minute that it would take 1000 bacteria to cover the point of a pencil. The size of a bacterial cell ranges from 0.2 microns to 10 microns and on an average is 1 micron in size. They can be seen through the oil immersion lens of a compound microscope. They can



be identified by their shape, size and cell arrangement. Four shapes are observed: rod-shaped, spherical, spiral and comma- shaped.

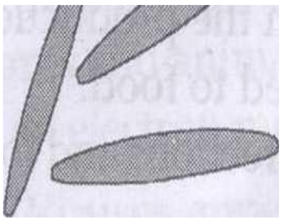
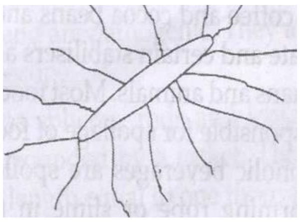
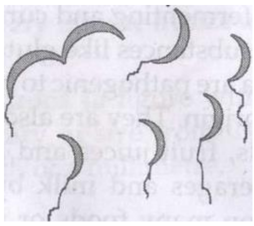
Rod-shaped bacteria They may or may not have organs of locomotion called flagella. Some species are capable of forming a resistant structure called an endospore. The bacteria in this group cause typhoid, tuberculosis and food poisoning. Some coliform bacteria (so called because they are present in the colon) which are part of the normal flora of the intestines of humans are also rod shaped and are indicators of faecal pollution. They are undesirable in foods because their presence may indicate the possibility of other enteric pathogens. Enteric pathogens are microorganisms that cause diseases of the intestinal tract or enteron.

Spherical bacteria They are also called cocci and may be arranged in many different ways.

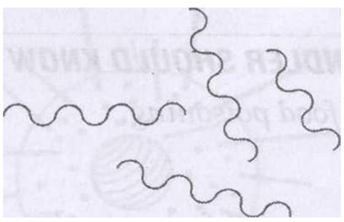
1. Pairs of cocci are called diplococci, for example, bacteria causing pneumonia.
2. Chains of cocci are called streptococci, for example, bacteria causing sore throat and tonsillitis.
3. Irregular clusters are known as staphylococci, for example, bacteria causing Staph food poisoning.
4. Tetrads are cubes of four to eight cocci, for example, bacteria causing spoilage of foods.

Spiral bacteria They are also called spirilla and cause diseases such as syphilis.

Comma-Shaped bacteria They are also called vibrios and cause diseases such as cholera.

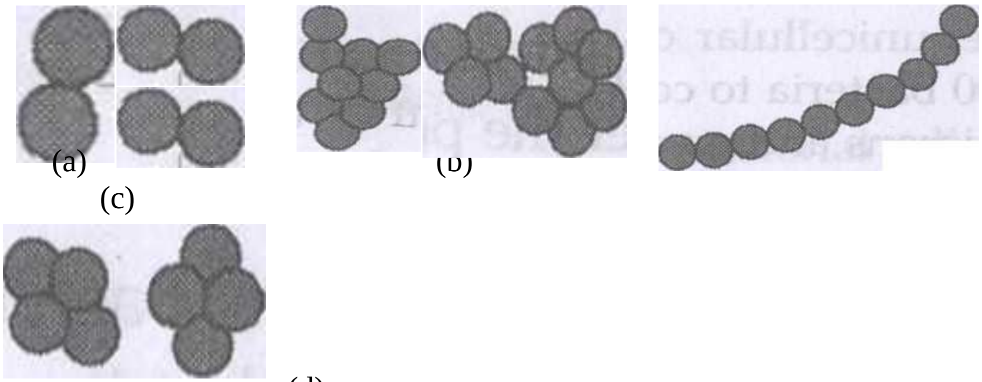




Escherica coli Salmonella
Campylobacter



Lactobacilli Treponema

Fig. 1.5.1 Different shapes of bacteria



(a) (b) (c) (d)

Fig 1.5.2 Cell arrangements in cocci (a) diplococci, (b) staphylococci,(c), (d) tetrads

Flagella Some bacteria are motile in liquids and swim about by means of hair-like structures called flagella. Flagella may be present singly or in clusters at one or both ends or all around the cell.

Capsule and Slime Layer Some bacteria may be surrounded by a capsule or a slime layer. This covering has a protective function and increases resistance to adverse conditions such as heat or chemicals. The capsule or slime layer is responsible for sliminess or ropiness of contaminated food.

Endospores Bacteria of the genera Bacillus and Clostridium, which cause food poisoning, are capable of producing a resistant structure within the cell. This structure is called an endospore. The endospore or spore is a resting body and is formed when conditions are unfavorable for growth. The cell gradually disintegrates leaving the spore intact. These spores are resistant to unfavorable conditions like high temperature, desiccation and some chemicals.

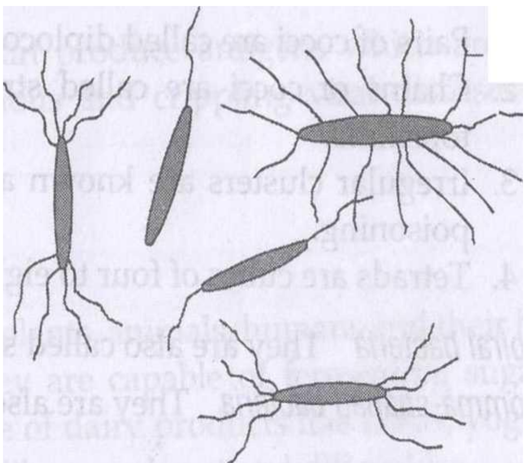
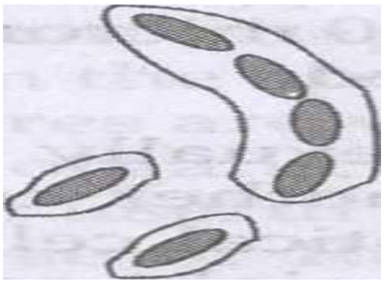


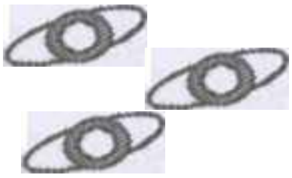
Fig. 15.3 Flagellated bacteria

They can remain dormant for a long time. That is why it is necessary to calculate the time and temperature required to destroy most heat resistant spores when canned foods have to be sterilised. These sporing bacteria are responsible for some of the spoilage of foods and for causing food poisoning. When spores settle on a suitable food supply, they germinate into vegetative cells and multiply very rapidly.

Reproduction When suitable conditions for growth exist, bacteria reproduce by dividing themselves into two every 20 or 30 minutes. This process of cell division is called binary fission. When a bacterial cell grows to its maximum size, a constriction appears at both sides of the centre axis. This constriction grows inwards



Slime layer



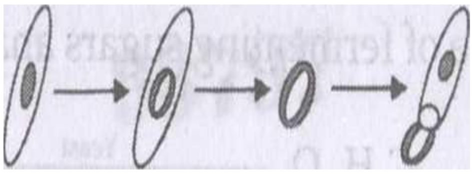


Fig. 1.5.4 Capsule and Slime layer

(a)Bacillus cereus (b)Unfavorable Conditions Favorable conditions
Fig. 1.5.5 (a) Endospores seen in certain spore- bearing (b) endospore formation and germination and divides the cell into two new cells. By this division a single bacterium can produce approximately two million bacteria in seven hours and 7000 million after 12 hours under optimum conditions for growth by multiplying every 20 minutes. When the environment becomes unsuitable for growth, i.e., when nutrients are exhausted or waste products accumulate, the cell dies. The food handler should realise that a single bacterium seldom occurs in food and after multiplication for a couple of hours the number of bacteria increases dramatically and the food becomes potentially hazardous.

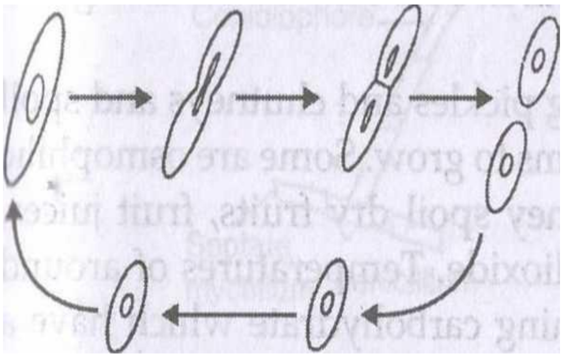


Fig. 1.5.6 Binary fission

Bacteria live and multiply in many food stuffs. Very often the type of food, atmospheric temperature and humidity of the kitchen provide ideal conditions for multiplication of bacteria. Protein rich foods Ji£e meat, fish and poultry, whether raw or cooked, are excellent media for bacterial growth, especially when these foods are stored without refrigeration.

Check your progress - 3
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.
5. What is bacteria and its types?
6. What are the shapes of bacteria?

5. What is bacteria and its types?

Bacteria are found everywhere — in and on soil, water, air, plants, animals, humans and their food. Bacteria are both useful and harmful to humans. They are capable of fermenting sugar to lactic acid. This makes them important in the manufacture of dairy products like curds, yoghurt, buttermilk and cheese, and fermented vegetable products like sauerkraut and dill pickles.

Some bacteria can oxidise ethyl alcohol to acetic acid and are necessary for the manufacture of vinegar. They leaven idli, dosa and dhokla batters and develop desirable flavours in them.

They help in fermenting and curing coffee and cocoa beans and in the production of enzymes, acids and other substances like glutamate and certain stabilisers added to food.

Many bacteria are pathogenic to humans and animals. Most food infections and food poisonings, ire of bacterial origin. They are also responsible for spoilage of food.

6. What are the shapes of bacteria?

- Rod-shaped bacteria
- Spherical bacteria
- Spiral bacteria
- Comma-Shaped bacteria

1.6 MORPHOLOGY AND CULTURAL CHARACTERISTICS IT'S IMPORTANCE

1.6.1 Morphological and cultural characterization

Morphological and cultural characters of the selected actinomycetes strains were studied by inoculating the selected strain into sterile ISP media. The media were sterilized and poured into sterile Petri dish. After solidification of the media, the culture of the selected strain was streaked on the media surface aseptically and incubated at 27 °C for 7 days. Morphological properties such as colony characteristics, type of areal hyphae, growth of vegetative hyphae, fragmentation pattern and spore formation were observed.

1.6.2 Microscopical characterization Gram staining method

A smear of the selected strain (A-4) was prepared on a clean glass slide and the smear was allowed to air-dry and then heatfixed. The heat-fixed smear was flooded with crystal violet and after one minute, it was washed with water and flooded with mordant Gram's iodine. The smear was decolorized with 95 % ethyl alcohol, washed with water and then counter-stained with safranin for 45 s. After washing with water, the smear was dried with tissue paper and examined under oil immersion (100 x).

1.6.3 Cultural Characters

Culture medium plays a key role in the demonstration of bacterial colony characters and the real morphology of the bacteria. The media consisting of simple ingredients and without any inhibitory substances are suitable for describing the colony characters of a bacterium (nutrient agar). Bacterial colonies vary in shape, size (measured in diameter), odor, color (pigmented), texture, and degree of adherence to the media (pitting and crusting). Different bacteria show different colony morphologies that include those such as rhomboidal in shape (e.g., Pseudomonas spp.), large mucoid colonies (e.g., Klebsiella spp.), colonies with wavy edges (e.g., Bacillus anthracis), swarming colonies (e.g., Proteus spp.); the colonies can be mucoid (M colonies), smooth (S colonies), and dry (R colonies). An M colony appears water-like, glistening, and confluent (no individual or separated colony) and is a character of a bacterial colony that produces slime or a capsule [Figure 1.6.1]. S colonies are recognized by their moist nature, and are indicators of freshly isolated wild bacterial strains. R colonies are rough, dry, granulated, and mutant types of bacteria that lack most of the surface proteins including the capsule and lipopolysaccharides. R colonies are formed by bacteria that are usually avirulent. The ability to show variations in both smooth-rough (S-R) ways and from rough to smooth (R-S) colonies has also been observed in bacteria. The rough colonies formed on blood agar, which on Gram stain reveal gram-positive bacilli that form spores (aerobic spore-bearing bacilli), are usually ignored as laboratory contaminants. Large encapsulated bacteria appear viscous and shiny, whereas nonencapsulated bacteria form small and dull colonies.



Figure 1.6.1 Colony morphology of a capsulated bacterium

1.6.4 Cultural characteristics of Staphylococcus aureus

- Staphylococci grow readily on most bacteriologic media under aerobic or microaerophilic conditions.
- Colonies on solid media are round, smooth, raised, and glistening.
- S. aureus usually forms gray to deep golden yellow colonies.
- Mannitol Salt Agar: circular, 2–3 mm in diameter, with a smooth, shiny surface; colonies appear opaque and are often pigmented, golden yellow.

1.6.5 Biochemical characteristics of Staphylococcus aureus

- Catalase positive
- Oxidase negative
- OF test – fermentative
- Coagulase positive: presence of free and /or bound coagulase
- Indole negative
- Gas negative
- Hydrogen sulphide negative
- Methyl red positive
- VP positive
- Nitrate reduction positive
- Gelatin hydrolysis positive
- Beta hemolysis on Blood agar
- Citrate positive
- Motility negative
- PYR negative
- Urease positive

Check your progress - 4

Notes: a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

6. Why is it important to determine colony cultural characteristics?

7. What is the importance of describing the cultural colonial characteristics of bacteria?

6. Why is it important to determine colony cultural characteristics?

Morphological and cultural characters of the selected actinomycetes strains were studied by inoculating the selected strain into sterile ISP media. The media were sterilized and poured into sterile Petri dish. After solidification of the media, the culture of the selected strain was streaked on the media surface aseptically and incubated at 27°C for 7 days. Morphological

properties such as colony characteristics, type of areal hyphae, growth of vegetative hyphae, fragmentation pattern and spore formation were observed.

7. What is the importance of describing the cultural colonial characteristics of bacteria?

Culture medium plays a key role in the demonstration of bacterial colony characters and the real morphology of the bacteria. The media consisting of simple ingredients and without any inhibitory substances are suitable for describing the colony characters of a bacterium (nutrient agar). Bacterial colonies vary in shape, size (measured in diameter), odor, color (pigmented), texture, and degree of adherence to the media (pitting and crusting). Different bacteria show different colony morphologies that include those such as rhomboidal in shape (e.g., Pseudomonas spp.), large mucoid colonies (e.g., Klebsiella spp.), colonies with wavy edges (e.g., Bacillus anthracis), swarming colonies (e.g., Proteus spp.); the colonies can be mucoid (M colonies), smooth (S colonies), and dry (R colonies). An M colony appears water-like, glistening, and confluent (no individual or separated colony) and is a character of a bacterial colony that produces slime or a capsule [Figure 1.6.1]. S colonies are recognized by their moist nature, and are indicators of freshly isolated wild bacterial strains. R colonies are rough, dry, granulated, and mutant types of bacteria that lack most of the surface proteins including the capsule and lipopolysaccharides. R colonies are formed by bacteria that are usually avirulent. The ability to show variations in both smooth-rough (S-R) ways and from rough to smooth (R-S) colonies has also been observed in bacteria. The rough colonies formed on blood agar, which on Gram stain reveal gram-positive bacilli that form spores (aerobic spore-bearing bacilli), are usually ignored as laboratory contaminants. Large encapsulated bacteria appear viscous and shiny, whereas nonencapsulated bacteria form small and dull colonies.

1.7 LET US SUM UP

In this unit we have discussed fundamentals of Microbiology and development of Microbiology Bacteria also touched upon briefly. The Morphology and cultural characteristics also analyzed. In this the importance of Microbiology discussed in detail.

1.8 UNIT- END- EXERCISES

1. What is fundamental of microbiology?
2. What is the basic concept of microbiological science?
3. Who is known as father of microbiology?
4. Why is it important to study microbiology?
5. What is bacteria and its types?
6. What are the three classifications of bacteria?
7. How many types of bacterias are there?
8. What are 5 characteristics of bacteria?
9. Why is it important to determine colony cultural characteristics?

10. What is the importance of describing the cultural colonial characteristics of bacteria?
11. Why is it useful to examine colony morphology?
12. What is microbiology morphology?

1.9 ANSWER TO CHECK YOUR PROGRESS

1. A) False, some microbes are useful for example microbes present in the intestinal flora which disease
   B) True
   C) True
2. Food microbiology is a branch of microbiology concerned with the relationship between microorganism and food. It covers food borne disease, food hygiene, food spoilage, fermented foods and beverages, use of microorganisms to produce food ingredients, microbiological aspects of quality control, microbiological analysis of food legislation.
3. A) Probiotics refers to microorganisms and their culture products which contribute to the intestinal balance, that benefitting the host by protection against disease or improvising the nutrition.
   B) Biotechnology is a series of enabling technologies that involve the manipulation of living organisms of their sub- cellular compounds to make or modify products to improve plants or animals or to develop microorganisms for specific uses.
   C) Genetic modification is a technique for copying individual genes and transferring them to another living organism in order to incorporate or delete specific characteristics.

1.10 SUGGESTED READINGS

1. Adams MR and Moss MO (2000) Food Microbiology, 2nd edn. Royal Society of Chemistry, London.
2. Demain AL (2000) Microbial Technology. Trends in Biotechnology 18, 26–31.
3. Garbutt, J (1997) Essentials of Food Microbiology. Hodder Arnold, London. Hornsey IS (1999) Brewing. Royal Society of Chemistry, London.
4. Ratledge C and Kristiansen B (2001) Basic Biotechnology, 2nd edn. Cambridge University Press, Cambridge.
5. Smith JE (2004) Biotechnology, 4th edn. Cambridge University Press, Cambridge.

UNIT II – Yeast- Morphology- Culture- Physiology- Classification - Industrial importance of Yeast

2.1 Introduction
2.2 Objectives
2.3 Yeast
2.4 Morphology
2.5 Physiology
2.6 Industrial importance of Yeast
2.7 Let Us Sum Up
2.8 Unit- End- Exercises
2.9 Answer to check your Progress
2.10 Suggested Readings

2.1INTRODUCTION

Yeast, any of about 1,500 species of single-celled fungi, most of which are in the phylum Ascomycota, only a few being Basidiomycota. Yeasts are found worldwide in soils and on plant surfaces and are especially abundant in sugary mediums such as flower nectar and fruits. There are hundreds of economically important varieties of ascomycete yeasts; the types commonly used in the production of bread, beer, and wine are selected strains of Saccharomyces cerevisiae. Some yeasts are mild to dangerous pathogens of humans and other animals, especially Candida albicans, Histoplasma, and Blastomyces.

As fungi, yeasts are eukaryotic organisms. They typically are about 0.075 mm (0.003 inch) in diameter. Most yeasts reproduce asexually by budding: a small bump protrudes from a parent cell, enlarges, matures, and detaches. A few yeasts reproduce by fission, the parent cell dividing into two equal cells. Torula is a genus of wild yeasts that are imperfect, never forming sexual spores.

In food manufacture, yeast is used to cause fermentation and leavening. The fungi feed on sugars, producing alcohol (ethanol) and carbon dioxide; in beer and wine manufacture the former is the desired product, in baking it is the latter. In sparkling wines and beer some of the carbon dioxide is retained in the finished beverage. The alcohol produced in bread making is driven off when the dough is baked. The fermentation of wine and sourdough breads is often initiated by naturally occurring yeasts present in air. One yeast cell can ferment approximately its own weight of glucose per hour.

2.2 OBJECTIVES

After going through the unit you will be able to;

- Understand the meaning Yeast
- Gain the knowledge about characteristics Morphology
- Importance of yeast

- Know about yeast activities.

2.3 YEAST

Humans have consumed cereals since prehistoric times. In Mesopotamia, baked pastes of ground grain were consumed, while, in Egypt, leavened bread was prepared. For thousands of years, humans were unaware of the existence of yeasts but were able to use them not only for bread making but also for brewing. The fundamental role of yeasts and bacteria in fermentation processes was only discovered in the last century by Pasteur. Soon after this, Hansen established the use of pure cultures for brewing and baking. Until that time, bakers used spent brewer's yeast for leavening, or seeded the fresh dough with a small part of already leavened dough. The commercial production of yeast for baking purposes started after about 1850, and since then, yeast technology has grown into a highly productive and economic industry.

2.3.1 What is Yeast?

Yeast are single-celled fungi. As fungi, they are related to the other fungi that people are more familiar with, including: edible mushrooms available at the supermarket, common baker's yeast used to leaven bread, molds that ripen blue cheese, and the molds that produce antibiotics for medical and veterinary use.

Yeast cells are egg-shaped and can only be seen with a microscope. It takes 20,000,000,000 (twenty billion) yeast cells to weigh one gram, or 1/28 of an ounce, of cake yeast.

2.3.2 A tiny organism with a long name

The scientific name for the yeast that baker's use is Saccharomyces Cerevisiae, or "sugar-eating fungus". A very long name for such a tiny organism! This species of yeast is very strong and capable of fermentation, the process that causes bread dough to rise.

2.3.3 A fungus with a sweet tooth

Yeast cells digest food to obtain energy for growth. Their favorite food is sugar in its various forms: sucrose (beet or cane sugar), fructose and glucose (found in honey, molasses, maple syrup and fruit), and maltose (derived from starch in flour).

The process, alcoholic fermentation, produces useful end products, carbon dioxide (gas) and ethyl alcohol. These end products are released by the yeast cells into the surrounding liquid in the dough. In bread baking, when yeast ferments the sugars available from the flour and/or from added sugar, the carbon dioxide gas cannot escape because the dough is elastic and stretchable. As a result of this expanding gas, the dough inflates, or rises. Thus, the term "yeast-leavened breads" was added to the vocabulary of the world of baking.

2.3.4 Fermentation in nature

Fermentation occurs naturally in nature. For instance, many berries break open in late fall when they are overripe and full of sugar. Natural yeast organisms, so small they cannot be seen with the naked eye, lodge on the surface of these berries, which then become fermented and alcoholic.

2.3.5 It Keeps Things Running

You can get plenty of proteins and B vitamins from yeast-rich foods. Yeast keeps your digestive system healthy and in balance. The right

amount in your body helps your immune system do its job. Yeast is part of a healthy mix of bacteria in your gut. It can help you absorb vitamins and minerals from your food, and even fight disease.

2.3.6 It Can Get Out of Balance

A little yeast in your body is good for you. Too much can cause infections and other health problems. If you take antibiotics too often or use oral birth control, your body might start to grow too much yeast. This often leads to gas, bloating, mouth sores, bad breath, a coating on your tongue, or itchy rashes.

2.3.7 Your Immune System's Involved

If your immune system isn't at its best, yeast can overgrow in your body. Babies, older people, and those with diseases like diabetes or HIV infection can have weakened immune systems. Chemotherapy for cancer and steroids can zap your immune system, too. Sjogren's syndrome, which affects your immune system, can raise your risk of yeast infection.

2.3.8 All about Candida

It's the yeast most often to blame for health problems. Candida albicans is the most common strain. But there are least 20 candida species that cause infections in humans. Candida auris is a new fungus in this family that's a big concern. Hospital patients infected with it can get very ill and may not get help from antifungal drugs.

2.3.9 What Is a Yeast Infection?

If yeast is out of balance, you might get candidiasis, or a yeast infection. These most often affect your vagina, but you can also have thrush, a yeast infection in your mouth or throat. Too much yeast can trigger diarrhea or a skin rash. It's rare, but if yeast overgrows and gets into your blood, it could cause infection throughout your whole body.

2.3.10 Yeast Infection Signs

It has some telltale symptoms. Your vagina might burn and itch. You may spot a thick, white discharge that looks like cottage cheese. It won't have an odor. It might hurt when you pee or have sex. Thrush can cause white clumps inside your cheeks or on your tongue. Your mouth looks red, and it may burn so much that it's hard to swallow food.

2.3.11 Is Yeast Allergy a Thing?

Yes. Some people are allergic to yeast in foods like bread, vinegar, and beer. It can cause hives on your skin. A severe yeast allergy could make it hard to breathe or cause your throat to swell. You'll need to work with your doctor to figure out which yeasty foods cause an allergic reaction and cut them out of your diet. Baked goods leavened with yeast are common culprits.

2.3.12 Nutritional Yeast

Nutritional yeast doesn't cause infections. It's good for your body. It's rich in B vitamins that help you break down foods for natural energy. Zinc and iron in yeast build stronger bones and muscles. Nutritional yeast isn't the same as brewer's yeast. You can find it at a health-food store baked into crackers or chips. Sprinkle nutritional yeast on your popcorn or homemade sauces.

2.3.13 Brewer's Yeast

It's used to make beer. It can also grow on corn or other grains. It's rich in protein, B vitamins, and the mineral chromium, which helps keep your blood sugar levels in balance. Brewer's yeast has a bitter taste, so take it as a supplement. It might ruin the flavor if you sprinkle it on foods.

2.3.14 Red Yeast Rice

Not really yeast but a cultured grain, it's used in Chinese medicine to lower cholesterol. Red yeast rice products could be risky for your health, so it's best to avoid them. They may interact with cholesterol drugs called statins or cause the same side effects. Some red yeast rice products also contain citrinin, which could lead to kidney failure.

2.3.15 Kombucha

This popular drink made with yeast is a fermented tea with sugar added for taste. While some people claim kombucha prevents cancer or controls high blood pressure, there's little proof that it really works. It can even make you sick if it's brewed in a place that isn't clean, whether that's someone's home or a shop.

2.3.16 Kefir

This fermented dairy treat comes from the Caucasus region of Turkey, but you can find it in most supermarkets now. Kefir is made by adding yeasty grains to milk. It's a probiotic that helps keep your gut bacteria in balance. Kefir might help you treat diarrhea, irritable bowel syndrome, or eczema, although more research is needed. Low-fat dairy also builds strong, healthy bones.

2.3.17 What Foods Have Yeast?

You can add fermented foods and drinks to your diet for their health benefits. Yogurt with live, active cultures is easy to find. Top it with fresh fruit for an extra boost. Sauerkraut, pickles, and kimchi are zesty fermented treats. But some of these foods are preserved for long shelf life, so they may also have lots of sugar or sodium.

2.3.18 It Might Fight Cancer

New cancer drugs and screening tests that use yeast are in the works. Many genes involved in cancer are similar to those found in yeast, so they're easier to map and study. One project is using yeast to create new drugs to treat aggressive breast cancer linked to the BRCA gene.

2.3.19 Fresh Yeast

Fresh yeast, also called wet, cake, and compressed yeast, comes in small square cakes that are made of fresh yeast cells. These blocks of fresh yeast, often used by professional bakers, are comprised of 70 percent moisture, and therefore are quite perishable. If not used right away, fresh yeast can be stored in the refrigerator for up to only 3 days, so it should be bought in amounts that will be used quickly.

2.3.20 Dry Yeast

Dry yeast is the more convenient of the two types. It is granulated and comes in little 1/4-ounce packets (approximately 2 1/4 teaspoons) or loose in a jar. Once exposed to the air, it should be stored in the refrigerator.

There are two types of dry yeast: Active dry yeast and instant yeast. The only difference between the two are the size of the granules; active yeast has larger granules while instant has been ground into a finer texture. Instant is named as such because it can be added directly to other ingredients; it does not need to be dissolved in water before using as active

dry yeast does. Active dry yeast is dormant until proofed, which occurs when it is dissolved in a small amount of lukewarm water (about 110 F).

Instant yeast is also available as rapid or quick rising. This type of yeast includes enzymes and additives to help the dough rise faster. When using rapid-rise yeast, it will take half of the time to make bread rise, or if the recipe calls for two sets of rising times, you can skip one of them and proceed to kneading and shaping the loaves.

2.3.21 Tips Using Yeast

Yeast is basically used in baking bread versus baked desserts; when making desserts, leavening agents such as baking soda and baking powder are used, or sometimes self-rising flour. However, there are a few dessert recipes that call for yeast such as Christmas breads, sweet rolls, and bee sting cake.

If you are unsure if your yeast is still alive, you can easily test it. Pour about 1/2 cup lukewarm water into a bowl and sprinkle over the yeast along with a pinch of sugar. Stir, and let sit for a few minutes; if it completely dissolves and the liquid bubbles, it means the yeast is active.

Yeast needs warm temperatures to do its thing, so when placing the dough to rise make sure it is sitting in a place that is 70 to 80 F. And if your recipe includes a lot of eggs, butter, sugar, and milk, you may need a little more patience; these ingredients slow down the leavening process.

Check your progress - 1

Notes: a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

1. What is Yeast?
2. What is a Yeast infection?
3. Write the fermentation in nature?
4. Write a short note on Nutritional yeast.

1. What is Yeast?

Yeast are single-celled fungi. As fungi, they are related to the other fungi that people are more familiar with, including: edible mushrooms available at the supermarket, common baker’s yeast used to leaven bread, molds that ripen blue cheese, and the molds that produce antibiotics for medical and veterinary use.

Yeast cells are egg-shaped and can only be seen with a microscope. It takes 20,000,000,000 (twenty billion) yeast cells to weigh one gram, or 1/28 of an ounce, of cake yeast.

It’s a fungus. There are many kinds of yeasts. You use one type to make bread, another to brew beer. One called candida lives inside your body. If it grows out of control, you can get an infection. Yeast infections can strike your skin, feet, mouth, penis, or vagina. If your immune system is weak, you may be more likely to get one.

2. What is a Yeast infection?

If yeast is out of balance, you might get candidiasis, or a yeast infection. These most often affect your vagina, but you can also have thrush, a yeast infection in your mouth or throat. Too much yeast can

trigger diarrhea or a skin rash. It's rare, but if yeast overgrows and gets into your blood, it could cause infection throughout your whole body.

3. Write the Fermentation in nature?

Fermentation occurs naturally in nature. For instance, many berries break open in late fall when they are overripe and full of sugar. Natural yeast organisms, so small they cannot be seen with the naked eye, lodge on the surface of these berries, which then become fermented and alcoholic.

4. Nutritional Yeast

Nutritional yeast doesn't cause infections. It's good for your body. It's rich in B vitamins that help you break down foods for natural energy. Zinc and iron in yeast build stronger bones and muscles. Nutritional yeast isn't the same as brewer's yeast. You can find it at a health-food store baked into crackers or chips. Sprinkle nutritional yeast on your popcorn or homemade sauces.

2.4 MORPHOLOGY OF YEAST

The morphology essential in the classification and identification of yeasts includes the description of the shape, size, and internal structure of the yeast cells; the changes during the reproduction of vegetative cells and the position of the newly formed cells to their parent; the changes the cells undergo during sexual activities, when forming resting cells, ballistospores or ascospores; the size, shape, surface of spores, their number per ascus, and mode of germination; and the appearance of a yeast growth visible to the naked eye, referred to as macroscopical appearance. The morphological changes connected with ascospore formation and sexual activities will be discussed here separate from their genetic importance.

2.4.1 The yeast cell.

The shape of the yeast cell and its structural parts are alternatively described as tridimensional objects, such as sphere, globe, egg shaped, cylindrical, olive shaped, and so on, or as two dimensional pictures as they appear through the microscope, like circular, elliptical, triangular, bottle shaped, and so on.

The size and shape of cells within a strain are the same when the yeast is propagated under identical conditions; they may change with the nutrient and the environment. Some strains produce overwhelmingly one cell form. Others may, as a rule, propagate in several shapes, which characteristic is often referred to as dimorphism if two shapes predominate and polymorphism if more than two cell forms occur.

The standard vegetative cells of S. cerevisiae, the most typical in appearance and most widely used domesticated yeast, are egg shaped, elliptical, or occasionally spherical with typical dimensions of 4 to 8 ,I in diameter for spheres, and 4 to 7 by 7 to 10 ,u for the elliptical cells. In old cultures, especially in pellicles grown on liquid surface, they also form filament-like, elongated sausage shaped cells. The other yeasts are either more spherical or more elongated than S. cerevisiae or have different shapes. Species of genus Torulopsis (Torula) form perfect spheres; Saccharomyces ellipsoideus (a variant of S. cerevisiae), Saccharomyces pastorianus, the species of genus Schizosaccharomyces, and many others usually form somewhat lengthier and more cylindrical shaped cells than S. cerevisiae; species of Saccharomycodes, Nadsonia, Hanseniaspora and

Kloeckera, produce mainly lemon-shaped cells; the cells of yeasts belonging to genus Trigonopsis are usually triangular; those of Pityrosporum are club or bottle shaped; species of many Candida, Eremothecium, Ashbya, and Eremascus
principally form elongated threads (the last three genera are not true yeasts).

2.4.2 Structure of the yeast cell.

The interior of the actively propagating yeast cells does not show internal structure without staining, while the older cells, the resting cells, and the cells forming or containing as cospores show some internal structure without staining. By various staining technics many structural parts can be demonstrated in all yeast cells.

2.4.3 Yeast: morphology and life cycle

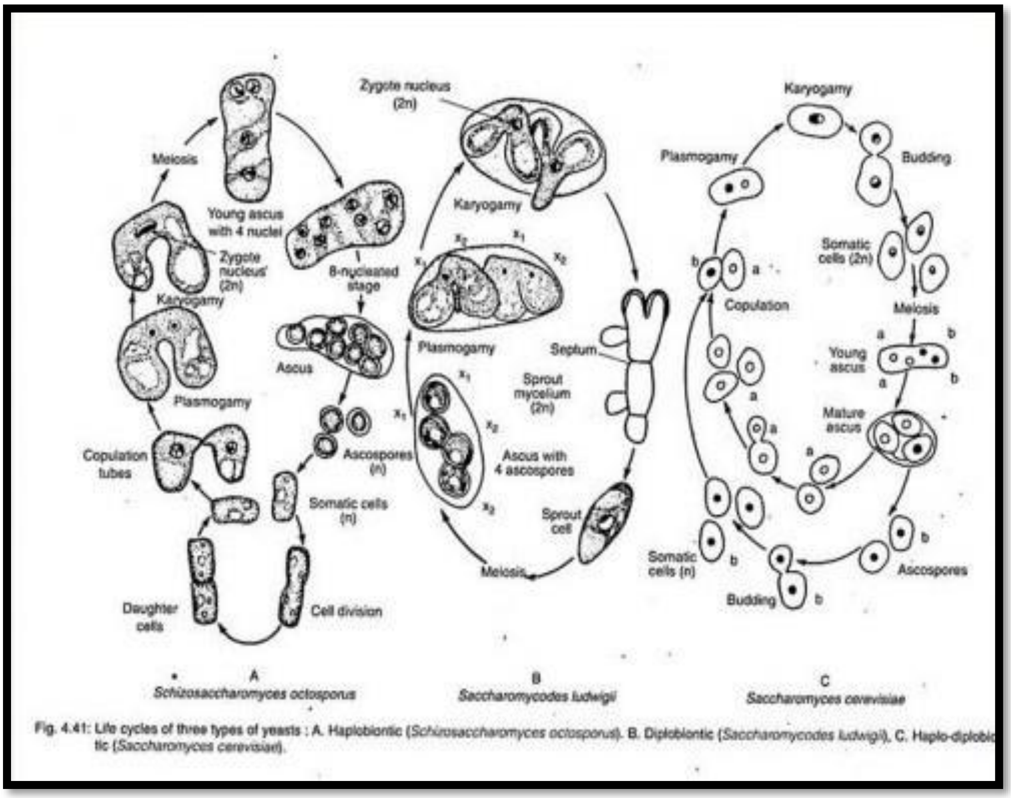


Fig 2.4.1 Life Cycle of three types of Yeasts

- ❖ They are single celled fungi
- ❖ Size: generally larger than most bacteria; (1-5) um wide and (5 30) um length
- ❖ Shape: cell is egg shaped, some are elongated or spherical
- ❖ Size and shape varies among species
- ❖ Yeast cell lacks flagella and other organ of locomotion.

2.4.4 Morphology of yeast cell

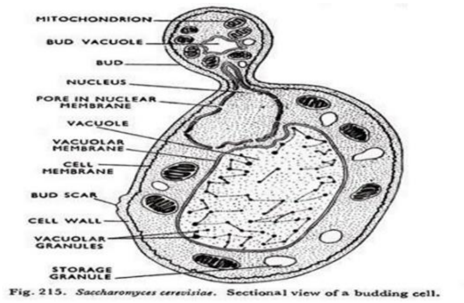


Fig. 2.4.2 Sccharamyces cerevisian, Sectional of a Budding Cell

- cell wall: composed of thin chitinous cell wall
- The protoplasm is surrounded by cell membrane which contains all the usual cell organelles like ribosomes, mitochondria, ER, nucleus and other granules
- Vacuole is single, large and centrally located.

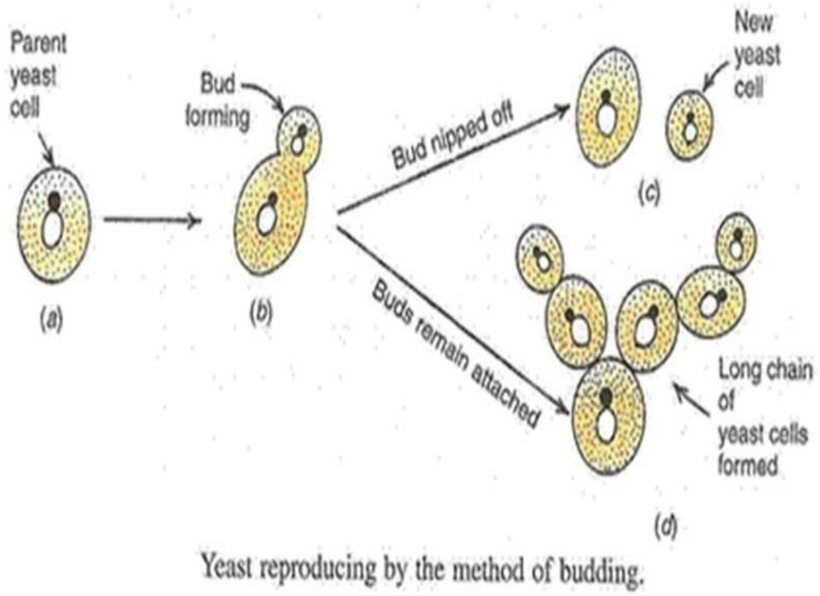
2.4.5 Reproduction in yeast cell

- Yeasts generally reproduce by Asexual method such as Budding or fission,
- Yeasts lacks sex organs (anthridium and oogonium)
- Sexual reproduction in yeast is highly variable

2.4.5.1 Budding

- It Occurs during abundant supply of nutrition
- Parent nucleus divides and moves toward daughter cell
- Enzymatic activities increases,
- Increased turger pressure acts on weaker part of cell wall and bud erupts
- Septum formation and bud separates into individual cell

Fig. 2.4.3 Yeast reproducing by the method of budding



2.4.5.2 Sexual reproduction

Sexual reproduction is highly variable in yeasts

Three different pattern of life cycle found in different genus

i. Haplodiplobiontic life cycle

ii. Haplobiontic life cycle
iii. Diplobiontic life cycle

2.4.6 Life cycle of Saccharomyces cerevisiae: Haplodiplobiontic life cycle

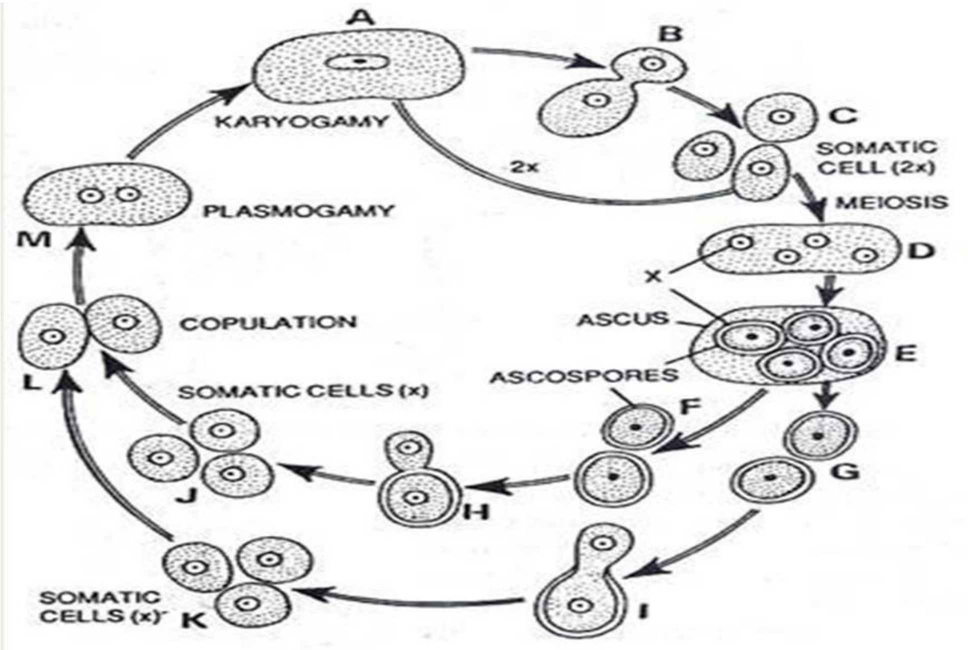


Fig. 2.4.4 life cycle of Saccharomyces cerevisiae: Haplodiplobiontic life cycle

- ❖ This cycle occurs in Saccharomyces cerevisiae
- ❖ In this life cycle somatic cell of yeast exists in two form (Haploid dwarf cell and Diploid large cell)
- ❖ Haploid cell contains two mating types “a” and “α”
- ❖ During favorable condition each of the haploid cell multiply by budding only
- ❖ If these mating types comes in contact with each other, they form gametangia and starts sexual reproduction
- ❖ Fusion of these two haploid cell form large fusion cell called Plasmogamy
- ❖ Nucleus also fused by karyogamy to form zygote
- ❖ Zygote multiply by budding and forms several diploid cells
- ❖ these diploid cells are larger than haploid cells
- ❖ Like haploid cell, these large diploid cells also live independent life and reproduce by budding
- ❖ Under unfavourable condition, diploid large cell become spherical and directly behaves as ascus mother cell
- ❖ Nucleus of ascus mother cell divides by meiosis to form 4- haploid nuclei

Check your progress - 2
Notes: a) Write your answers in the space given below.

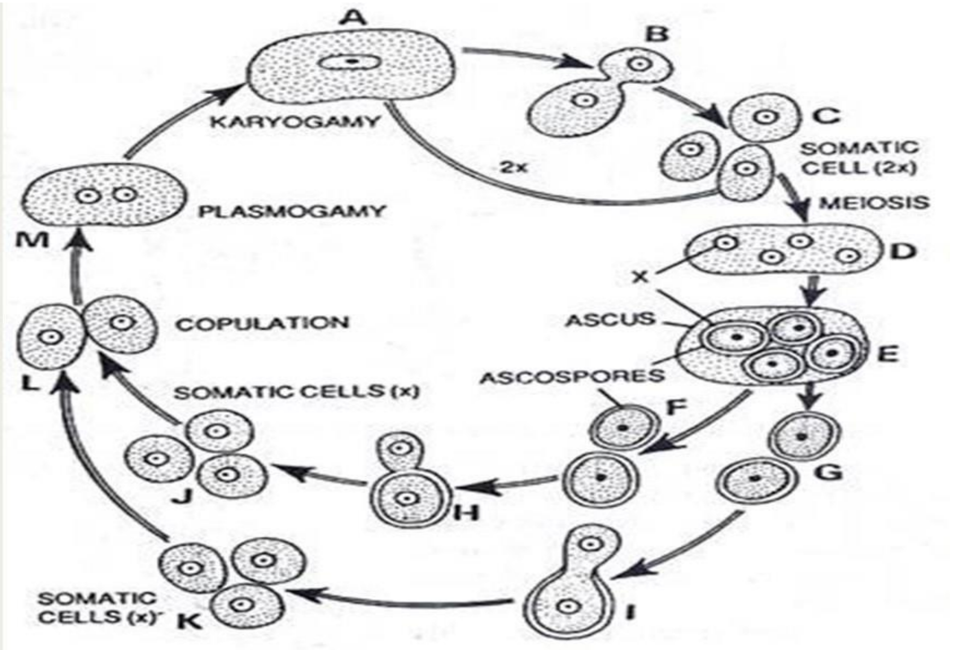
b) Compare your answers with those given at the end of the unit.

5. How does yeast reproduce?
6. What is the shape of Saccharomyces cerevisiae?

5. How does yeast reproduce?

- Yeasts generally reproduce by Asexual method such as Budding or fission,
- Yeasts lacks sex organs (anthridium and oogonium)
- Sexual reproduction in yeast is highly variable

6.What is the shape of Saccharomyces cerevisiae?



- This cycle occurs in Saccharomyces cerevisiae
- In this life cycle somatic cell of yeast exists in two form (Haploid dwarf cell and Diploid large cell)
- Haploid cell contains two mating types “a” and “α”
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- Fusion of these two haploid cell form large fusion cell called Plasmogamy
- Nucleus also fused by karyogamy to form zygote
- Zygote multiply by budding and forms several diploid cells
- these diploid cells are larger than haploid cells
- Like haploid cell, these large diploid cells also live independent life and reproduce by budding
- Under unfavourable condition, diploid large cell become spherical and directly behaves as ascus mother cell

- Nucleus of ascus mother cell divides by meiosis to form 4- haploid nuclei
- Out of 4-nuclei, 2 belongs to mating type “a” and t2 belongs to “α”

- Each nuclei gather some cytoplasm and becomes ascospore
- Each ascospore is globular and thick walled structure and relased by rapture of ascus wall.
- Ascospore germinates to give haploid dwarf cell.

2.5 YEASTS OF CULTURE AND INDUSTRIAL IMPORTANCE OF YEAST

2.5.1 Yeasts and Yeast-Like Fungi

Yeasts are eukaryotic micro-organisms classified in the kingdom Fungi, with the 1500 species currently described estimated to be only 1 per cent of all yeast species. Most reproduce asexually by budding, although a few do so by mitosis. Yeasts are unicellular, although some species with yeast forms may become multicellular through the formation of a string of connected budding cells known as pseudohyphae, or false hyphae, as seen in most moulds. Yeast size can vary greatly depending on the species, typically measuring 3^ jim in diameter, although some yeasts can reach over 40 jam.

The yeast species Saccharomyces cerevisiae has been used in baking and in fermenting alcoholic beverages for thousands of years.

2.5.2 Yeast Cultures

The benefit of the yeast culture comes from the metabolites produced during the fermentation process. It is suggested that the metabolites stimulate the bacteria in the hind gut of the horse, increasing their activity which results in an increase in digestion of feeds by the bacteria. The increase in activity is a result of changes in the bacteria population found in the hind gut. Moore found that the bacteria which digest fibre in the hind gut of the horse increased in numbers when the horses were supplemented with yeast culture. This increase in numbers can result in more nutrients from the feed being available to the horse. Research has shown that horses fed diets supplemented with yeast culture digested more of the dry matter and fibre than did supplemented horses. The digestion of fibre in the horse results in the production of volatile fatty acids which the horse uses as a source of energy.

2.5.3 Physiological Characteristics

Although species of yeasts may differ considerably in their physiology, those of industrial importance have enough physiological characteristics in common to permit generalisations, provided that it is kept in mind that there will be exceptions to every statement made.

In general, sugars are the best source of energy for yeasts, although oxidative yeast, e.g. the film yeasts, oxidase organic acids and alcohol. Carbon dioxide produced by bread yeasts accomplishes the leavening of

bread, and alcohol made by the fermentative yeasts is the man product in the manufacture of wines, beer, industrial alcohol, and other products. They yeasts also aid in the production of flavors or 'bouquet' in wines.

Nitrogenous foods utilized vary from simple compounds such as ammonia and urea to amino acids and polypeptides. In addition, yeasts require accessory growth factors.

Yeasts may change in their physiological characteristics, especially the true, or ascospore-forming, yeasts which have a sexual method of reproduction. These yeasts can be bred for certain characteristics or may mutate to new forms. Most yeasts can be adapted to conditions which previously would not support good growth. Illustrative of different characteristics within a species in the large number of strains of Saccharomyces cerevisiae suited to different uses, e.g. bread strains, beer strains, wine strains, and high-alcohol-producing strains or varieties.

More than bread and beer: The National Collection of Yeast Cultures

Yeasts are one of the earliest, if not the earliest, biological tools used by people. The earliest known written words in human history document recipes for making bread and beer, both of which are made using yeast, as well the price of bricks – it seems our fancy for food and drink while discussing the price of property has remained unchanged over the years.

The stone age didn't end because we ran out of stone, and the oil age won't end because we run out of oil. We'll find better, more renewable and more environment friendly ways of making fuels, and yeast have a plethora of genes to do this," says Dr Ian Roberts, Curator of the National

Collection of Yeast Cultures (NCYC), based at the Institute of Food Research, which receives strategic funding from BBSRC, and is based on Norwich Research Park.

"What we're looking for is yeast as an enabling technology. The ultimate aim is that students of the future will program yeast genomes just as students today programme computer applications," says Roberts.

The NCYC looks to the future – its part of the Synthetic Yeast 2.0 programme for example – but it also serves the present needs of industry: identifying, DNA sequencing and preserving more than 4000 pure reference samples worth millions to brewing and biotechnology companies around the world. This level of knowledge and the skills base for industry make it a BBSRC-funded National Capability and not just a facility.

And the NCYC can even delve into the past by helping microbreweries to resurrect traditional ale recipes using old yeast strains stored for decades in liquid nitrogen. This meets the growing demand for 'nostalgia beers' and supporting Britain's multi-billion pound brewing industry as well as increasingly important areas of the rural economy.

2.5.4 Culture club

The yeast collection was first founded in 1948 when British brewers realized the value of their yeast cultures and put them in safe deposit to keep them secure. Roberts's estimates there are a good 4-500 strains from beer brewers in the NCYCs present collection, including Saccharomyces carlsbergensis for example – the yeast from the original Carlsberg lager brewery.

The NCYC then evolved into a broader collection and moved to IFR in 1981, collecting food spoilage yeast able to evade the conventional food preservatives. In 1999 the collection became a part of The United Kingdom

National Culture Collection (UKNCC), which was established to co-ordinate the activities of Britain's national collections of microbial organisms – there are equivalents in the bacteria, algae and viral worlds.

All of these collections are vital to the UK's bioeconomy, and in 2012 the NCYC became a BBSRC-funded National Capability, consolidating support for it to continue its core activities and expand into new projects. "The National Capability enables us to launch various products and services on the back of the capability we have, so in addition to providing services such as identification and safe deposit we can do a host of other research-oriented activities," says Roberts.

These operations include identification and sequencing services using the advanced DNA sequencing techniques, which are available in-house as well as nearby at The Genome Analysis Centre (TGAC). "If a company has found an interesting new yeast species or has a problem with a particular contaminant, even if we can't tell you what it is we can tell you what it's most similar to using DNA sequencing methodology."

2.5.5 Chain reaction

The modern applications of yeast are in industrial biotechnology, and a key focus of the NCYC's activities is utilising yeast that can produce fuels and chemicals. To do this, they feed different strains into an advanced experimental biorefinery located on-site at IFR, metabolising the sugars in agri-food waste substrates such as wheat straw and waste biomass into liquid transport biofuels.

The researchers are keen to extend the range of substrates that yeast can use and make them more robust. This is because when wheat straw, for example, is broken up a lot of chemical inhibitors are released which slows the beneficial metabolic reactions. Roberts says that strains used in brewing cannot work in the more rigorous environment of highly variable biomass, so they're looking for different yeast strains, or using them in combination, that can overcome these inhibitors.

2.5.6 Gene genie

Yeasts are also at the forefront of efforts to create not just engineered organisms, but entirely new classes of microorganisms. In 2009 Craig Venter, a geneticist and pioneer of the Human Genome Project, revealed what he described as the world's first synthetic organism: his team transferred the genome of a bacterium into a yeast, modified it by altering methyl groups (which affect how DNA is used) and then transplanted into another bacterium. Then in 2011, a different team made yeast with partially 'artificial chromosomes' recreated using DNA sequencing. The introduced DNA contained a 'scrambling' element that could be switched on or off, and would lead to a greater number of mutant yeasts in order to search for ones better suited to making certain compounds and metabolites.

2.5.7 Pub life

Yeasts have an integral part to play in solving the problems of the present and the future, but that does not mean that traditional uses have been forgotten. Tastes have changed – people are buying less of the continental lagers that were considered sophisticated in the 1980s. Instead, traditional ale sales in the UK have increased along with the establishment of small 'microbreweries' that produce fewer, often premium, products.

As part of the movement, traditional ale enthusiasts have looked to the past to recreate old brews in what had been dubbed 'nostalgia brewing', and for that they need the yeast that were used at the time, which is where the NCYC can help.

2.5.8 Yeast can turn substrates such as wheat straw into biofuels

"Regenerating those ales is of growing interest," says Roberts. "We don't have ancient beers but we do have the yeast that were used to generate the ancient beers, and often the recipes are still available in the brewing industry. So to revive a traditional ale if they have the recipe and we have the yeast they can put the two together and create a beer appropriate for the market."

And although ale-drinking conjures up images of rotund, red-faced fellows in country pubs with a dog and a shotgun at the ready, the modern reality is anything but – ales are the emerging drink of fashionistas from London to Lyme Regis. And the growth in ale drinking counters the trend in pub closures and an overall drop in alcohol intake per person in the UK. Taking into account that brewing in Britain is a multi-billion pound industry, this means the value of a national resource of brewing yeast alone is something to drink to.

2.5.9 Keeping, counting and transporting yeast

Dr Steve James, a yeast molecular taxonomist based at the NCYC, explains his role and interest in yeast biodiversity, as well as how they are stored and sent around the world.

My particular interest is in yeast biodiversity from various habitats, and in expanding the general diversity in the collection to use academically and industrially. So far the total number of yeast species discovered is around 1500, and a conservative estimate is that there are 10 to 100 times more to be found. And literally it's just a matter of going into habitats that have not yet been looked at. We've got ongoing collaborations with colleagues in Ecuador taking students into cloud and rainforest environments, which haven't been looked at before from a yeast perspective. We've already identified three or four new species and this is just touching the bottom of the cloud forest.

2.5.10 Classification and Identification of Yeasts

The true yeasts are in the subdivision Ascomcotina, and the false or asporogenous, yeasts are in the subdivision Fungi imperfecti or Deuteromycotina.

The principal bases for the identification and classification of genera of yeast are as follows:

1. Whether ascospores are formed.
2. If they are spore-forming:
    a) The method of production of ascospores:
        (i) Produced without conjugation of yeast cells (parthenogenetically). Spore formation may be followed by: (a) conjugation of ascospores, and (b) conjugation of small daughter cells.
        (ii) Produced after isogamic conjugation (conjugating cells Appear similar).
        (iii) Produced by heterogamic conjugation (conjugating Cells differ in appearance).
    b) Appearance of ascospores: shape, size, and color. Most

Spores are spheroidal or ovoid, but some have odd shapes, e.g. most species of Hansenula, which look like derby hats.

3. Appearance of vegetative cells: shape, size, color, inclusions.
4. Method of asexual reproduction:
    1. Budding.
    2. Fission.
    3. Combined budding and fission.
    4. Arthrospores (oidia).
5. Production of a mycelium, pseudomycelium or no mycelium.
6. Growth as a film over surface of a liquid (film yeasts) or growth throughout medium.
7. Colour of macroscopic growth.
8. Physiological characteristics (used primarily to differentiate species or strains within a species):
    a. Nitrogen and carbon sources.
    b. Vitamin requirements.
    c. Oxidative or fermentative: film yeasts are oxidative; other yeasts may be fermentative of fermentative and oxidative.
    d. Lipolysis, urease activity, acid production or formation of starchlike compounds.

2.5.11 Yeasts of Industrial Importance Schizosaccharomyces

Schizosaccharomyces is a genus of fission yeasts. The most well-studied species is S. pombe. Like the distantly related Saccharomyces cerevisiae, S. pombe is a significant model organism in the study of eukaryotic cell biology. It is particularly useful in evolutionary studies because it is thought to have diverged from the Saccharomyces cerevisiae

lineage between 300 million and 1 billion years ago, and thus provides an evolutionarily distant comparison (Fig. 2.17).

1) Saccharomyces

Saccharomyces is a genus in the kingdom of fungi that includes many species of yeast. Saccharomyces is from Greek (sugar) and (mushroom) and means sugar fungus. Many members of this genus are considered very important in food production. One example is Saccharomyces cerevisiae, which is used in making wine, bread, and beer. Other members of this genus include Saccharomyces bay anus, used in making wine, and Saccharomyces boulardii, used in medicine.

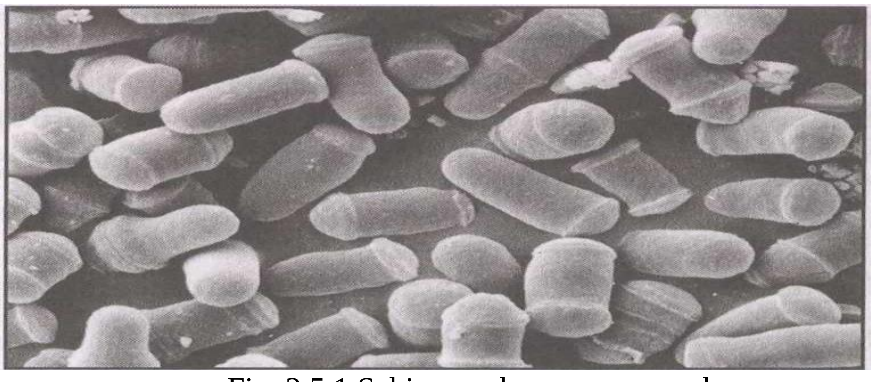


Fig. 2.5.1 Schizosaccharomyces pombe.

Colonies of Saccharomyces grow rapidly and mature in three days. They are flat, smooth, moist, glistening or dull, and cream to tannish cream in colour. The inability to use nitrate and ability to ferment various carbohydrates are typical characteristics of Saccharomyces.

2) Kluyveromyces

Kluyveromyces is a genus of ascomycetous yeasts in the family Saccharomycetaceae. Some of the species, such as K. marxianus, are the teleomorphs of Candida species.

3) Zygosaccharomyces

Zygosaccharomyces is a genus of yeast in the family Saccharomycetaceae. The yeast has a long history as a spoilage yeast within the food industry. This is mainly because it is tolerant to many of the common Ibod preservation methods. The biochemical properties it possesses to achieve this includes high sugar tolerance (50-60 per cent), high ethanol tolerance (up to 18 per cent), high acetic acid tolerance (2.0-2.5 per cent), very high sorbic and benzoic acid tolerance (up to 800-1000 mg/1), very high molecular S02 tolerance (greater than 3 mg/1) and high xerotolerance.

4) Pichia

Pichia (Hansenula and Hyphopichia are obsolete synonyms) is a genus of yeasts in the family Saccharomycetaceae with real spherical, elliptical or oblong acuminate cells. Pichia is a teleomorph, and forms during sexual reproduction hat-shaped, hemispherical or round ascospores. The anamorphs of some Pichia species are Candida species. The asexual reproduction is by multilateral budding.

Today more than 100 species of this genus are known. Some of them interfere with the fermentation process for alcohol production. Most are found in decaying plants, some live in close symbiosis with insects, which live on decaying plants.

5) Hansenula polymorpha

Hansenula polymorpha (Pichia angusta) is a methylotrophic yeast with unusual characteristics. It is used as a protein factory for pharmaceuticals.

Hansenulapolymorpha (Pichia angusta) belongs to a limited number of methylotrophic yeast species (yeasts that can grow on methanol). The range of methylotrophic yeasts includes Candida boidinii, Pichia methanolica, Pichia pastoris and Hansenula polymorpha. H. polymorpha is taxonomically a species of the Saccharomycetaceae family. The leading taxonomy monographs follow a recent proposal to merge the genera Pichia and Hansenula and to re-name H. polymorpha as Pichia angusta. However, many scientists desire to maintain the popular name H. polymorpha.

6) Debaryomyces

Deboryomyces is a genus of yeasts in the family Saccharomycetaceae.

7) Hanseniaspora

These lemon-shaped (apiculate) yeasts grow in fruit juices. Nadsonia yeasts are large and lemon-shaped.

8) Fungi Imperfecti

The Fungi imperfecti or imperfect fungi, also known as Deuteromycota, are fungi which do not fit into the commonly established taxonomic classifications of fungi that are based on biological species

concepts or morphological characteristics of sexual structures because their sexual form of reproduction has never been observed; hence the name 'imperfect fungi'. Only their asexual form of reproduction is known, meaning that this group of fungus produces their spores asexually.

9) Candida (fungus)

Candida is a genus of yeasts. Many species of this genus are endosymbionts of animal hosts including humans. While usually living as commensals, some Candida species have the potential to cause disease. Clinically, the most significant member of the genus is Candida albicans, which can cause infections (called candidiasis or thrush) in humans and other animals, especially in immunocompromised patients. Many Candida species are members of gut flora in animals, including C. albicans in mammalian hosts, whereas others live as endosymbionts in insect hosts.

10) Brettanomyces

Brettanomyces is a non-spore forming genus of yeast in the family Saccharomycetaceae, and is often colloquially referred to as4Bretf. The genus name Dekkera is used interchangeably with Brettanomyces, as it describes the teleomorph or spore forming form of the yeast. The cellular morphology of the yeast can vary from ovoid to long 'sausage' shaped cells. The yeast is acidogenic and when grown on glucose rich media produce large amounts of acetic acid. Brettanomyces is important to both the brewing and wine industries due to the sensory compounds it produces. In the wild, Brettanomyces lives on the skins of fruit.

11) Kloeckera

These are imperfect apiculate or lemon-shaped yeasts. K. apiculata is common on fruits and flowers and in the soil.

Check your progress - 3

Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.

7. What are the industrial uses of yeast?
8.Classification and identification of yeast?

7. What are the industrial uses of yeast?

Schizosaccharomyces is a genus of fission yeasts. The most well-studied species is S. pombe. Like the distantly related Saccharomyces cerevisiae, S. pombe is a significant model organism in the study of eukaryotic cell biology. It is particularly useful in evolutionary studies because it is thought to have diverged from the Saccharomyces cerevisiae lineage between 300 million and 1 billion years ago, and thus provides an evolutionarily distant comparison

8. Classification and Identification of Yeasts?

yeasts are in the subdivision Ascomcotina, and the false or asporogenous, yeasts are in the subdivision Fungi imperfect or Deuteromycotina.The principal bases for the identification and classification of genera of yeast are as follows:

1. Whether ascospores are formed.
2. If they are spore-forming.

3. Method of asexual reproduction.
4. Budding.
5. Fission.
6. Combined budding and fission.
7. Arthrospores (oidia).
8. Production of a mycelium, pseudomycelium or no mycelium.
9. Growth as a film over surface of a liquid (film yeasts) or growth
10. throughout medium.
11. Colour of macroscopic growth.
12. Physiological characteristics (used primarily to differentiate
13. species or strains within a species):

2.6 LET US SUM UP

In this unit, we looked at the concept of Yeasts and the importance of Yeasts Cell and the in general, egg shaped.
Then we studied about some of the important Morphology and Culture, their structure, mode of reproduction and diseases spread by them. We also discussed about favorable and unfavorable conditions that affect the growth of these Yeasts
The last part of the unit focused on Classification and Industrial importance of Yeasts genetically modified foods were highlighted in this section.

2.7 UNIT- END- EXERCISES

1. What exactly is Yeast?
2. Is yeast good for health?
3. Where is yeast found?
4. How does yeast reproduce?
5. What is the shape of Saccharomyces cerevisiae?
6. How can you tell if a microscope is under a yeast?
7. What are yeast cells?
8. What are the industrial uses of yeast?
9. What is the importance of yeast in baking industry?
10. What is yeast culture?
11. What is the medical significance of yeast?

2.8 ANSWER TO CHECK YOUR PROGRESS

1. Yeasts
   a. Unicellularfimgi,
   b. largerthan bacteria, w
   c. hich multiply
   d. by budding.
1. Yeasts may be useful or harmful in foods.
2. Yeast fermentations are involved in the manufacture of foods such as bread, beer, wines, vinegar, and surface-ripened cheese, and yeasts are grown for enzymes and for food.
3. Yeasts are undesirable when they cause spoilage of
   a. sauerkraut,
   b. fruit juices,
   c. syrups,

d. molasses,
e. honey,
f. jellies,
g. meats,
h. wine,
i. beer and other foods

2.9 SUGGESTED READINGS

1. Wheals, A. E., Rose, A. H. and Harrison, J. S. (Eds.): The Yeast, Volume 6, Second edition, Yeast Genetics. Academic Press, London (1995).
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UNIT III – Molds- Morphology- Physiology and Multiplication – Significance of Molds – Common household molds in relation to food science

3.1. Introduction
3.2. Objectives
3.3. Molds
3.4. Morphology
3.5 Physiology and Multiplication
3.6 Signification of molds
3.7 Common household molds in relation to food science
3.8 Let Us Sum Up
3.9 Unit- End- Exercises
3.10 Answer to check your Progress
3.11 Suggested Readings

3.1 INTRODUCTION

Food microbiologists must become acquainted with the microorganisms important in foods, at least to an extent that will enable them to identify the main types in order to make use of what is known about their characteristics and compare results with those of order workers. The first section of this chapter briefly outlines the identification and classification of food molds, because these organisms are not studied much in the usual beginning course in microbiology. These is some discussion of the classification of yeast, but no attempt has been made to cover determinative bacteriology, a subject to which the student usually receives an adequate introduction in a first course in microbiology.

3.2 OBJECTIVES

After going through the unit you will be able to;

- Know the various reproductive Structure of Molds
- Explain the requirements for their growth;
- Learn the classification of these Molds based on their characteristics; and
- Distinguish between the useful and harmful Molds.

3.3 MOLDS

Mold growth on foods, with its fuzzy or cottony appearance, sometimes colored, is familiar to everyone, and usually food with a moldy or "mildewed" food is considered unfit to eat. While it is true that molds are involved in the spoilage of many kinds of foods, special molds are useful in the manufacture of certain foods or ingredients of foods. Thus, some kinds of cheese are moldripened, e.g., blue, Roquefort, Camembert, Brie, Gammelost, etc., and molds are used in-making Oriental foods, e.g., soy sauce, miso, sonti, and others discussed later. Molds have been grown

As food or feed and are employed to produce products used in foods, such as amylase for breadmaking or citric acid used in soft drinks. Some mold do produce various toxic metabolites (mycotoxins).

3.3.1 General Characteristics of Molds

The term "mold" is a common one applied to certain multicellular, filamentous fungi whose growth on foods usually is readily recognized by its fuzzy or cottony appearance. The main part of the growth commonly appears white but may be colored or dark or smoky. Colored spores are typical of mature mold of some kinds and give color to part or all of the growth. The thallus, or vegetative body, is characteristic of thallophytes, which lack true roots, stems, and leaves.

Morphological Characteristics

The morphology, i.e., the form and structure, of molds, as judged by their macroscopic and microscopic appearance, is used in their identification and classification.

3.3.2 Hyphae and Mycelium

The mold thallus consists of a mass of branching, intertwined filaments called hyphae (singular hypha), and the whole mass of these hyphae is known as the mycelium. The hyphae may be submerged, or growing within the food, or aerial, or growing into the air above the food. Hyphae also may be classed as vegetative, or growing, and hence involved chiefly in the nutrition of the mold, or fertile, involved in the production of reproductive parts. In most molds the fertile, hyphae are aerial, but in some molds they may be submerged. The hyphae of some molds are full and smooth, but the hyphae of others are characteristically thin and ragged. A few kinds of molds produce sclerotia (singular sclerotium), which are tightly packed masses of modified hyphae, often thick-walled, within the mycelium. These sclerotia are considerably more resistant to heat and other adverse conditions than is the rest of the mycelium, and for this reason they may be important in some processed food products.

Septate hyphae increase in length by means of division of the tip cell (apical growth) or of cells within the hypha (intercalary growth), the type of growth being characteristic of the kind of mold. Division of the nuclei distributed throughout nonseptate hyphae is accompanied by an incease in the length of filaments.

Special mycelial structures or part aid in the identification of molds. Examples are the rhizoids, or "holdfasts," of Rhizopus and Absidia, the foot cell in Aspergillus, and the dichotomous, or Y-shaped, branching in Geotrichum, which are all described subsequently.

3.3.3 Reproductive Parts or Structures

Molds can grow from a transplanted piece of mycelium. Reproduction of molds is chiefly by means of asexual spores. Some molds also form sexual spores. Such molds are termed "perfect" and are classified as either Oomycetes or Zygomycetes if nonseptate, or Ascomycetes or Basidiomycetes if septate, in contrast to "imperfect" molds, the Fungi Imperfecti (typically septate), which have only asexual spores.

3.3.4 A sexual Spores

The asexual spores of molds are produced in large numbers and are small, light, and resistant to drying. They are readily spread through the air to alight and start new mold thallus where conditions are favorable. The three principal types of asexual spores are (1) conidia (singular conidium) (Figure 2.1), (2) arthrospores, or oidia (singular oidium) (Figure 2.2), and (3) sporangiospores (Figure 2.3). Conidia are cut off, or bud, from special fertile hyphae called conidiophores and usually are in the open, i.e., not enclosed in any container, in contrast to the sporangiospores, which are in a sporangium (plural sporangia), or sac, at the tip of a fertile hypha, the sporangiophore. Arthrospores are formed by fragmentation of a hypha, so that

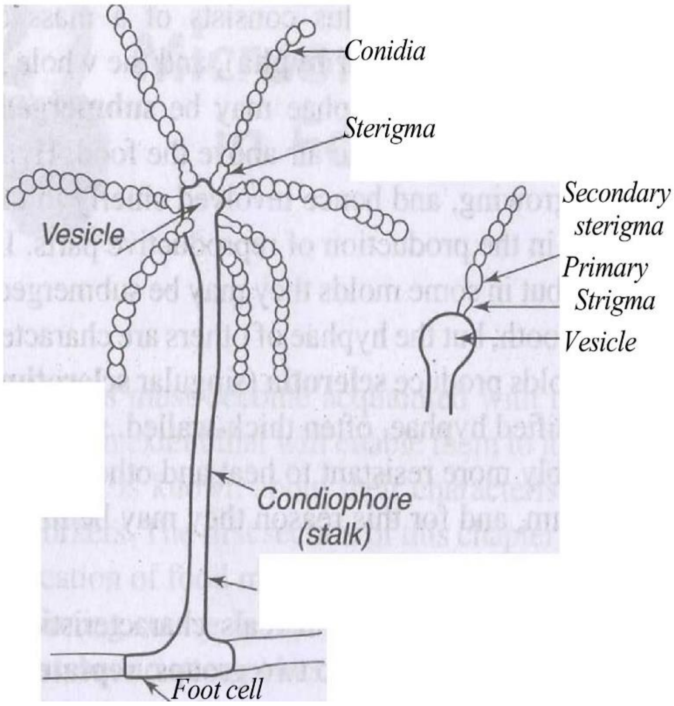


Fig. 3.3.1 Diagram of a simple conidial head of Aspergillus.

The cells of the hypha become arthrospores. Examples of these three kinds of spores will be given in the discussion of important genera of molds. A fourth kind of asexual spore, the chlamydospore, is formed by many species of molds when a cell here and there in the mycelium stores up reserve food, swells, and forms a thicker wall than of surrounding cells. This chlamydospore, or resting cell, can withstand unfavorable conditions better than ordinary mold mycelium can and later, under favorable conditions, can grow into a new mold.

The morphology of the asexual spores is helpful in the identification of genera and species of molds. Sporangiospores differ in size, shape, and color. Conidia not only vary in these respects but also may be smooth or roughened and one-, two-, or many-celled.

Also helpful in the identification of molds is the appearance of the fertile hyphae and the asexual spores on them. If sporangiospores are formed, points to be noted are whether the sporangiospores are simple or

branched, the type of branching, and the size, shape, color, and location of the sporangia.

The swollen tip of the sporangiospore, the columella, which usually projects into the sporangium, assumes shapes typical of species of mold. Conidia may be borne singly on conidiophores or in spore heads of differing arrangement and complexity. A glance at the general appearance of a spore head often is sufficient for identification of the genus. Some molds have conidia in chains, squeezed off one by one from a special cell, a sterigma (plural sterigmata) or phialide, at the tip of the conidiophore. Other molds have irregular masses of Conidia, which cut off from the tip of the conidiophore without evident sterigmata. These masses of

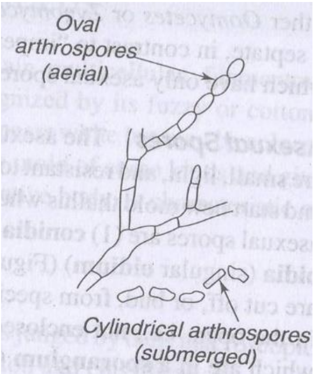


Fig.3.3.2 Geotrichum

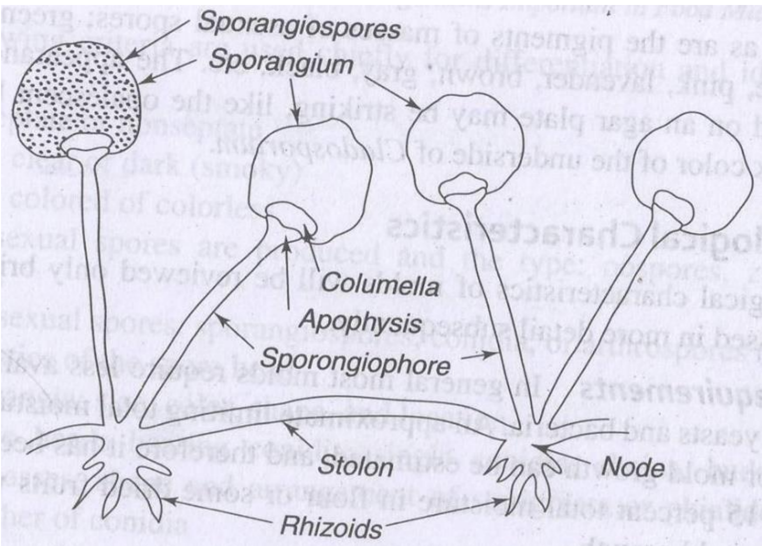


Fig.3.3.4 Rhizopus.

Conidia may be loosely or tightly packed or even ensiled. The conidia of some molds bud from the conidiophore and continue to multiply by budding; they appear yeast like.

3.3.5 Sexual Spores

The molds which can produce sexual spores are classified on the basis of the manner of formation of these spores and the types produced. The nonseptate molds (JPhycomycet.es) that produce oospores are termed Oomycetes. These molds are mostly aquatic; however, included in this

group are several important plant pathogens, i.e., the "downy mildews" which cause late blight of potatoes and buckeye rot of tomatoes. The oospores are formed by the union of a small male gamete and a large female gamete. The Zygomycetes from zygospores by the union of the tips of two hyphae which often appear similar and which may come from the same mycelium or from different mycelia. Both oospores and zygospores are covered by a tough wall and can survive drying for long periods. The Ascomycetes (septate) from sexual spores known as ascospores, which are formed after the union of two cells from the same mycelium or from two separate mycelia. The ascospores, resulting from cell division after conjugation, are in an ascus, or sac, with usually eight spores per ascus. The asci may be single or may be grouped within a covering called an ascocarp, formed by branching and interwining adjacent hyphae. The Basidiomycetes, which include most mushrooms, plant rusts, smuts, etc., form a fourth type of sexual spore, the basidiospore.

3.3.6 Cultural Characteristics

The gross appearance of a mold growing on a food often is sufficient to indicate its class or order. Some molds are loose and fluffy; others are compact. Some look velvety on the upper surface, some dry and powdery, and others wet or gelatinous. Some molds are restricted in size, while others seem limited only by the food or container. Definite zones of growth in the thallus distinguish Some molds, e.g., Aspergillus niger. Pigments in the mycelium—red, purple, yellow, brown, gray, black, etc— are characteristic, as are the pigments of masses of asexual spores; green, blue-green, yellow, orange, pink, lavender, brown, gray, black, etc. The appearance of reverse side of a mold on an agar plate may be striking, like the opalescent blue-black or eenish-black color of the underside of Cladosporium.

3.3.7 Physiological Characteristics

The physiological characteristics of molds will be reviewed only briefly here and will be discussed in more detail subsequently.

3.3.8 Moisture Requirements

In general most molds require less available moisture than do most yeasts and bacteria. An approximate limiting total moisture content of a given food for mold growth can be estimated, and therefore it has been claimed that below 14 to 15 percent total moisture in flour or some dried fruits will prevent or greatly delay mold growth.

3.3.9 Temperature Requirements

Most molds be considered mesophilic i.e., able to grow well at ordinary temperatures. The optimal temperature for most molds is around 25 to 30 C, but some grow well at 35 to 37 C or above, e.g., Aspergillus spp., and some at still higher temperatures. A number of molds are psychrotrophic; i.e., they grow fairly well at temperatures of refrigeration, and some can grow slowly at temperatures below freezing. Growth has been reported at as low as -5 to -10C. A few are thermophilic; i.e., they have a high optimal temperature.

3.3.10 Oxygen and pH Requirements

Molds are aerobic; i.e., they require oxygen for growth; this is true at least for the molds growing on foods. Most molds can grow over a wide range of hydrogen-ion concentration (pH 2 to 8.5), but the majority are favored by an acid pH.

3.3.11 Food Requirements

Molds in general can utilize many kind of foods, ranging from simple to complex. Most of the common molds possess a variety of hydrolytic enzymes, and some are grown for their amylases, pectinases, proteinases, and lipases.

3.3.12 Inhibitors

Compounds inhibitory to other organisms are produced by some molds, such as penicillin from penicillium chrysogenum and clavacin from Aspergillus clavatus. Certain chemical compounds are mycostatic, inhibiting the growth of molds (sorbic acid, propionates, and acetates are examples), or are specifically fungicidal, killing molds.

Initiation of growth of molds is slow compared to that of bacteria or yeasts, so that when conditions are favorable for all these organisms, molds usually lose out in the competition. After mold growth is under way, however, it may be very rapid.

3.3.13 Classification and Identification of Molds

Molds are plants of the kingdom Myceteae. They have no roots, stem, or leaves and are devoid of chlorophyll. They belong to the Eumycetes, or true fungi, and are subdivided further to subdivision, classes, orders, families, and genera.

The following criteria are used chiefly for differentiation and identification of molds:

1. Hyphae septate or nonseptate
2. Mycelium clear or dark (smoky)
3. Mycelium colored of colorless
4. Whether sexual spores are produced and the type: oospores, zygospores, or ascospores
5. Types of asexual spores: sporangiospores, conidia, or arthrospores (oidia)
6. Characteristics of the spore head
    a. a.Sporangia: size, color, shape, and location
    b. b.Spore heads bearing conidia: single conidia, chains, budding conidia, or masses; shape and arrangement of sterigmata or phialides; gumming together of conidia.
7. Appearance of sporangiophores or conidiophores: simple or branched, and if branched the types of branching; size and shape of columella at tip of sporangiophore; whether conidiophores are single or in bundles
8. Microscopic appearance of the asexual spores, especially of conidia: shape, size, color; smooth or rough; one-, two-, or many-celled
9. Presence of special structures (or spores): stolons, rhizoids, foot cells, apophysis, chlamydospores, sclerotia, etc.

    An excellent introduction to the food-borne fungi has been prepared by Samson et al. (1984). Included in the text are illustrations of numerous food-borne molds, actual photomicrographs of molds, photographs of molds on agar surfaces, and a key to identification.

3.3.14 Molds of Industrial Importance

Several molds of industrial importance are outlined by genus, with typical morphological structures presented in the accompanying Figures.
Mucor Mucor (Figures 2.4 and 2.5) are involved in the spoilage of some foods and the manufacture of others. A widely distributed species is M. racemosus. M. rouxii is used in the "Airiyta" process for the saccharification of starch, and mucors help ripen some chesses (e.g., Gammelost) and are used in making certain Oriental foods.

3.3.15 Molds of Industrial Importance

Several molds of industrial importance are outlined by genus, with typical morpho¬logical structures presented in the accompanying Figures.

1) Mucor

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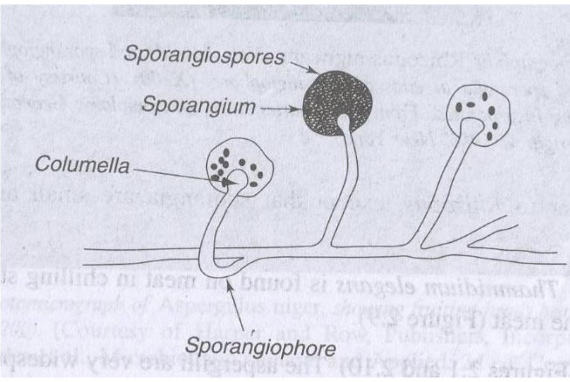


Fig.3.3.5 Mucor.

2) Sclerotinia

Some species cause rots of vegetables and fruits, where they are present in the conidial stage. The lemon-shaped conidia are in chains, with a "plug" separating conidia.

In the preceding discussion of molds important in foods, genera that only occasionally grow on specific foods have been omitted. They will be mentioned with those foods. For the descriptions of these genera, reference should be made to text and reference books on fungi listed at the end of this chapter.

3) Zygorrhynchus

These soil molds are similar to Mucor except that the zygospore suspensors are markedly unequal in size (Fig. 3.3.6).

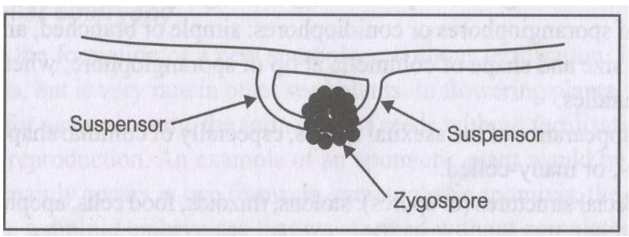


Fig. 3.3.6 Zygospore formation in Zygorrhynchus.

4) Rhizopus

Rhizopus is a genus of common saprobic fungi on plants and specialised parasites on animals. They are found on a wide variety of organic substrates, including 'mature fruits and vegetables', faeces, jellies, syrups, leather, bread, peanuts and tobacco. Some Rhizopus species are opportunistic agents of human zygomycosis (fungal infection) and can be fatal, Rhizopus infections are also an associated complication of diabetic ketoacidosis. The widespread genus contains about nine species (Fig. 3.3.7).

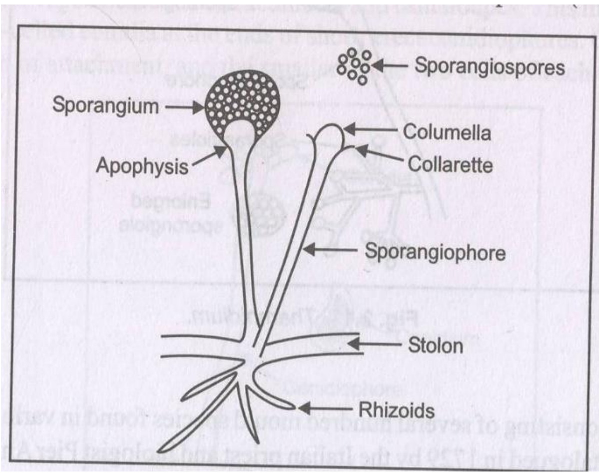


Fig. 3.3.7 Schematic diagram of Rhizopus spp.

5) Absidia

Absidia is a genus of fungi in the family Mucoraceae. The best known species is the pathogenic Absidia corymbifera, which causes zygomycosis, especially in the form of mycotic spontaneous abortion in cows. It can also cause mucormycosis in humans. It is an allergenic that could cause mucorosis in individuals with low immunity. It usually infects the lungs, nose, brain, eyesight and skin. Absidia spp. are ubiquitous in most environments. They are often associated with warm decaying plant matter, such as in compost heaps (Fig. 3.3.8).

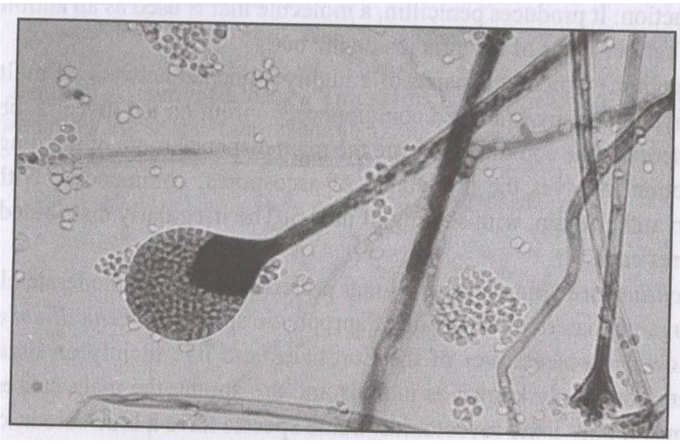


Fig. 3.3.8Mature sporangium of a absidia mold.

6) Thamnidium

Thamnidium elegans is found on meat in chilling storage, causing 'whiskers' on the meat (Fig. 3.3.9).

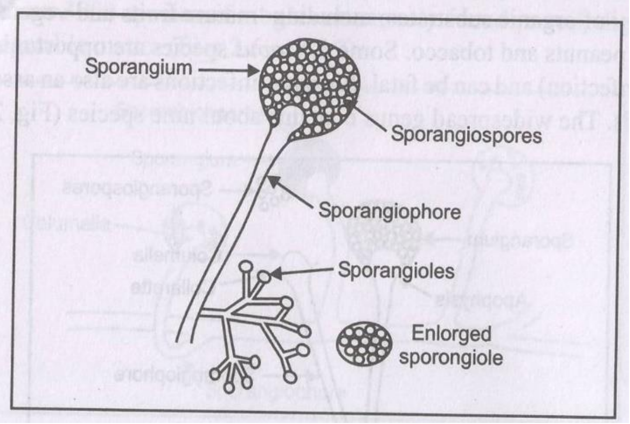


Fig. 3.3.9 Thamnidium.

7) Aspergillus

Aspergillus is a genus consisting of several hundred mold species found in various climates worldwide. Aspergillus was first catalogued in 1729 by the Italian priest and biologist Pier Antonio Micheli. Viewing the fungi under a microscope, Micheli was reminded of the shape of an aspergillum (holy water sprinkler), from Latin spargere (to sprinkle), and named the genus accordingly. Today 'aspergillum' is also the name of an asexual spore-forming structure common to all Aspergilli; around one-third of species are also known to have a sexual stage.

Aspergillus species are common contaminants of starchy foods (such as bread and potatoes), and grow in or on many plants and trees. *

8) Penicillium

Penicillium is a genus of ascomycetous fungi of major importance in the natural environment as well as food and drug production. It produces penicillin, a molecule that is used as an antibiotic, which kills or stops the growth of certain kinds of bacteria inside the body.

The thallus (mycelium) typically consists of a highly branched network of multinucleate, septate, usually colourless hyphae. Many-branched conidiophores sprout on the mycelia, bearing individually constricted conidiospores. The conidiospores are the main dispersal route of the fungi, and often green.

Sexual reproduction involves the production of ascospores, commencing with the fusion of an archegonium and an antheridium, with sharing of nuclei. The irregularly distributed asci contain eight unicellular ascospores each.

Species of Penicillium are ubiquitous soil fungi preferring cool and moderate climates, commonly present wherever organic material is available. Saprophytic species of Penicillium and Aspergillus are among the best-known representatives of the Eurotiales and live mainly on organic biodegradable substances. They are commonly known as molds and are among the main causes of food spoilage. Many species produce highly toxic mycotoxins. Some species have a blue colour, commonly growing on old bread and giving it a blue fuzzy texture.

9) Trichothecium

The common species, T. roseum (Fig. 3.3.10), is a pink mold which grows on wood, paper, fruits such as apples and peaches, and vegetables such as cucumbers and cantaloupes. This mold is easily recognised by the clusters of two-celled conidia at the ends of short, erect conidiophores. Conidia have a nipplelike projection at the point of attachment, and the smaller of the two cells of each conidium is at this end.

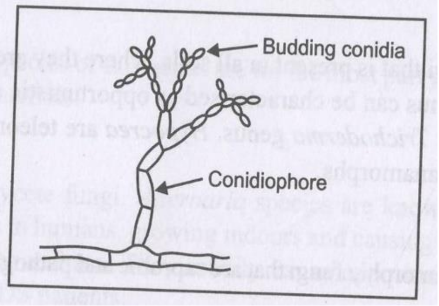


Fig. 3.3.10 Trichothecium.

10) Geotrichum

Geotrichum is a genus of fungi found worldwide in soil, water, air, and sewage, as well as in plants, cereals, and dairy products; it is also commonly found in normal human flora and is isolated from sputum and feces.

The genus Geotrichum includes several species. The most common species is Geotrichum candidum. Geotrichum clavatum and Geotrichum fici are among other Geotrichum species. Geotrichum fici has an intense smell resembling that of pineapple.

11) Neurospora

Neurospora is a genus of Ascomycete fungi. The genus name, meaning 'nerve spore' refers to the characteristic striations on the spores that resemble axons (Fig. 3.3.11).

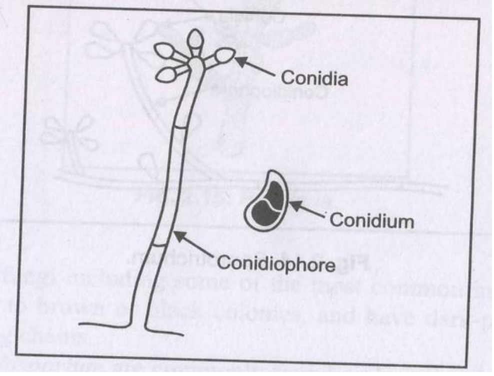


Fig.3.3.11 Neurospora(Monilia).

12) Sporotrichum

Among the saprophytic species is S. carnis (Fig. 3.3.12), found growing on chilled meats, where it causes

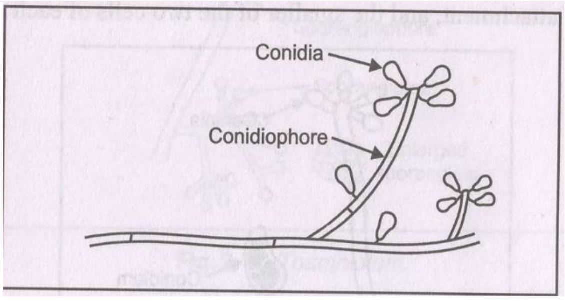


Fig. 3.3.12 Sporotrichum.

13) Botrytis

Botrytis may refer to:

1. Botrytis, the anamorphs of fungi of the genus Botryotinia.
    (a) Botrytis cinerea, a mold important in wine making.
2. Botrytis, the cauliflower cultivar group of Brassica oleracea.

14) Cephalosporium gramineum

Cephalosporium gramineum or Hymenula cerealis is a plant pathogen that causes Cephalosporium Stripe of wheat and other grasses. The disease can cause yield losses of up to 50 per cent by causing death of tillers and reducing seed production and seed size. The disease causes broad yellow or brown stripes along the length of the leaf and discolouration of the leaf veins

15) Trichoderma

Trichoderma is a genus of fungi that is present in all soils, where they are the most prevalent culturable fungi. Many species in this genus can be characterised as opportunistic avirulent plant symbionts.

There are 89 species in the Trichoderma genus. Hypocrea are teleomorphs of Trichoderma which themselves have Hypocrea as anamorphs.

16) Scopulariopsis

Scopulariopsis is a genus of anamorphic fungi that are saprobic and pathogenic to animals. The widespread genus contains 22 species.

17) Pullularia

Pullularia (Fig. 3.3.13) Ovate, hyaline conidia (blastospores of buds from preexisting cells) borne as lateral buds on all parts of the mycelium. Colonies are pale and slimy and yeastlike when young, becoming mycelial and dark and leathery in age. P. pullulans is a common species.

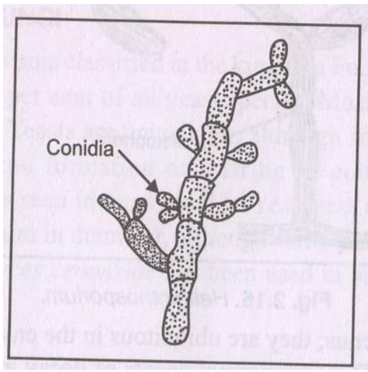


Fig. 3.3.13 Pullularia

18) Cladosporium

Cladosporium is a genus of fungi including some of the most common indoor and outdoor molds. Species produce olive-green to brown or black colonies, and have dark-pigmented conidia that are formed in simple or branching chains.

The many species of Cladosporium are commonly found on living and dead plant material. Some species are plant pathogens, others parasitise other fungi. Cladosporium spores are wind-dispersed and they are often extremely abundant in outdoor air. Indoors Cladosporium species may grow on surfaces when moisture is present.

Cladosporium fulvum, cause of tomato leaf mold, has been an important genetic model, in that the genetics of host resistance are understood.

The airborne spores of Cladosporium species are significant allergens, and in large amounts they can severely affect asthmatics and people with respiratory diseases. Prolonged exposure may weaken the immune system. Cladosporium species produce no major mycotoxins of concern, but do produce volatile organic compounds (VOCs) associated with odours.

19) Helminthosporium

Helminthosporium (Fig. 2.16) Species of this genus are for the most part plant pathogens but may grow saprophytically on vegetable materials.

20) Alternaria

Alternaria is a genus of ascomycete fungi. Alternaria species are known as major plant pathogens. They are also common allergens in humans, growing indoors and causing hay fever or hypersensitivity reactions that sometimes lead to asthma. They readily cause opportunistic infections in immuno-compromised people such as AIDS patients.

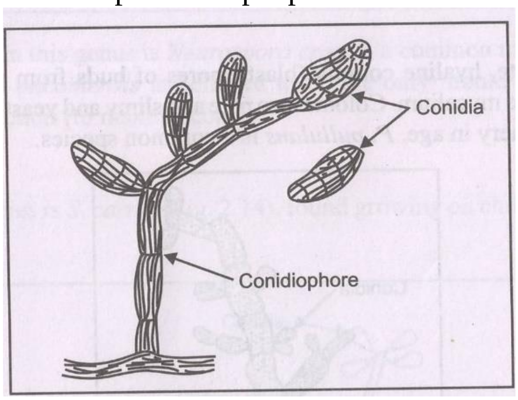


Fig. 3.3.14 Helminthosporium.

There are 299 species in the genus; they are ubiquitous in the environment and are a natural part of fungal flora almost everywhere. They are normal agents of decay and decomposition. The spores are airborne and found in the soil and water, as well as indoors and on objects. The club-shaped spores are single or form long chains. They can grow thick colonies which are usually black or gray.

At least 20 per cent of agricultural spoilage is caused by Alternaria species. Many human health disorders can be caused by these fungi, which

grow on skin and mucous membranes, including on the eyeballs and within the respiratory tract. Allergies are common, but serious infections are rare, except in people with compromised immune systems. However, species of this fungal genus are often prolific producers of a variety of toxic compounds. The effects most of these compounds have on animal and plant health are not well known. The terms alternariosis and alternariatoxicosis are used for disorders in humans and animals caused by a fungus in this genus.

21) Stemphylium

This, too, is a common genus. The conidia are dark and multicellular but have fewer cross walls than those a Alternaria and are rounded at both ends.

22) **Fusarium**

Fusarium is a large genus of filamentous fungi widely distributed in soil and in association with plants. Most species are harmless saprobes, and are relatively abundant members of the soil microbial community. Some species produce mycotoxins in cereal crops that can affect human and animal health if they enter the food chain. The main toxins produced by these Fusarium species are fumonisins and trichothecenes

23) Monascus

Monascus is a genus of mold. Among the 24 known species of this genus, the red-pigmented Monascus purpureus is among the most important because of its use in the production of certain fermented foods in East Asia, particularly China and Japan.

24) Sclerotinia

Sclerotinia is a genus of fungi in the family sclerotiniaceae. The widely species contains 14 species.

Check your progress -1
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.

1. What are the characteristics of molds?
2. To Write the Reproductive parts or structure?

1. What are the characteristics of molds?

The term "mold" is a common one applied to certain multicellular, filamentous fungi whose growth on foods usually is readily recognized by its fuzzy or cottony appearance. The main part of the growth commonly appears white but may be colored or dark or smoky. Colored spores are typical of mature mold of some kinds and give color to part or all of the growth. The thallus, or vegetative body, is characteristic of thallophytes, which lack true roots, stems, and leaves.

2. To Write the Reproductive parts or structure?

Molds can grow from a transplanted piece of mycelium. Reproduction of molds is chiefly by means of asexual spores. Some molds also form sexual spores. Such molds are termed "perfect" and are classified as either Oomycetes or Zygomycetes if nonseptate, or Ascomycetes or Basidiomycetes if septate, in contrast to "imperfect" molds, the Fungi Imperfecti (typically septate), which have only asexual spores

3.4 PHYSIOLOGY AND MULTIPLICATION

3.4.1 Physiology

Lambert (1930) revealed that Mycogone perniciosa is quite sensitive to prolonged exposure to moderately high temperature. The cardinal temperatures for growth of the organism on Thaxter's agar are 8°C, 24°C and 32°C. He also reported that in agar cultures M. perniciosa was killed by exposures to temperatures of 42°C (106°F) or higher for 6 hr. or more. According to Zaayen and Rutigens (1981) thermal death point for M. perniciosa is 48°C. Bech and Kovacs (1981) reported that aqueous suspension of Mycogone spores can withstand 42°C and 36°C for 10 minutes and 1 hr, respectively. Hsu and Han (1981) reported that optimum temperature for mycelial growth, sporulation and conidial germination was 25°C. He also recorded pH 6.0 as optimum for conidial germination. According to Liao (1981) chlamydospore failed to germinate on various media in vitro even after heat (40-70°C) treatment or application of chemicals and solvent. However, germination occurred on potato dextrose agar (PDA) medium exposed to the gas produced by mushroom mycelia in compost for 36 hrs at 24°C. In anthor study Bech and Kovacs (1981) found that aleurospores are unable to germinate in water, Richard's solution, pressed mushroom juice or in PDA but verticilloid spores showed a certain degree of germination in diluted mushroom juice and on PDA. As reported by Tu and Liao (1989) the pathogen is tolerant to a wide pH range in acid side and able to grow at pH 4.4, however, the growth becomes weaker or rather restricted at pH 8.4. Holland and Cooke (1991) reported that in malt extract agar medium M. perniciosa formed abundant thin walled, hyaline phialo conidia and thick walled pigmented verrucose conidia. During nutrient deplection other propagules appeared, namely, lateral smooth conidia, infected interculary cells, chlamydospores and arthro conidia. Singh and Sharma (2000) have reported on PDA. Optimum temperature and pH for growth were reported to be 25°C and 6.0, respectively. Mannose and asparagine have been reported as best sources of carbon and nitrogen, respectively. Sharma and Kumar (2000) observed compost extract agar medium as the best for the mycelial growth and malt extract peptone dextrose agar medium for spore production. A pH range 5-6 was found optimal for the mycelial growth.

3.4.2 General Characteristics

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3.4.3 Morpohological Characteristics

The morphology, i.e. the form and structure, of molds, as judged by their macroscopic and microscopic appearance, is used in their

identification and classification. Hyphae and Mycelium: The mold thallus consists of a mass of branched, intertwined filaments called hyphae (singular hypha), and the whole mass of these hyphae are known as the mycelium.

3.4.4 Reproductive Parts or Structures:

Molds can grow from a transplanted piece of mycelium. Reproduction of molds is chiefly by means of asexual spores. Some molds also form sexual spores.

3.4.5 Culture Characteristics

The gross appearance of a mold growing on a food often is sufficient to indicate its class or order. Some molds are loose and fluffy; others are compact. Some look velvety on the upper surface, some dry and powdery, and others wet or gelatinous. Some molds are restricted in size, while others seem limited only by the food or container. Pigments in the mycelium – red, purple, yellow, brown, gray black, etc. – are characteristic, as are the pigments of mass of asexual spores; green, blue-green, yellow, orange, pink, lavender, brown, gray, black, etc.

3.4.6 Physiological Characteristics

The physiological characteristics of molds will be reviewed only briefly here and will be discussed in more detail subsequently. Moisture Requirements: In general, most molds require less available moisture than do most yeasts and bacteria. It has been claimed that below 14 to 15 percent total moisture in flour or some dried fruits will prevent or greatly delay mold growth. Temperature Requirements: Most molds would be considered mesophilic i.e. able to grow well at ordinary temperature. The optimal temperature for most Introduction molds is around 25 to 30°C, but some grow well at 35 to 37°C or above, e.g. Aspergillus spp. And some at still higher temperatures.

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Check your progress -2

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3. What is morpohological characteristic?

4. Physiological Characteristics of Mold?

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3.5 SIGNIFICANCE OF MOLDS AND COMMON HOUSEHOLD MOLDS IN RELATION TO FOOD SCIENCE

3.5.1 The Molds of Greatest Importance to Foods

Main Groups:

1. **Deuteromycota (Fungi Imperfecti):** This is a class of septate fungi in which a sexual stage (perfect state) of the life cycle has not been observed. The Fungi Imperfecti are essentially a provisional taxonomic grouping; if a sexual stage is observed in a fungus assigned to this group, the organism will then be assigned a new name that reflects its perfect state.

    i. **Aspergillus** – Very important genus that includes species used in industrial fermentations and the production of enzymes and organic acids. It also includes several spoilage microorganisms and two species, A. flavus and A. parasiticus, which produce carcinogenic aflatoxins.
    ii. **Botrytis** – Cause grey mold rot in fruits.

iii. **Penicillium** – Like Aspergillus, this genus includes industrially important species as well as others that are involved in food spoilage and the production of mycotoxins.

2. **Ascomycota:** Septate mycelium, sexual reproduction characterized by the formation of a sac-like structure called an ascus. The ascus eventually ruptures and the enclosed spores are liberated. This is a very large class of fungi that includes the genera Byssochlamys, and the perfect states of some fungi formerly classified under Aspergillus.
   a. **Byssochlamys** – Form heat resistant spores that can survive heat treatment and result in the spoilage of high-acid canned foods, especially fruits.
3. **Zygomycota:** A diverse group of lower, filamentous fungi which have aseptate mycelium and are capable of rapid growth. This group has sexual and asexual modes of reproduction. Members include the genus Rhizopus, which olds several species that cause bread molds as well as R. oligosporus, a species used in oriental soybean fermentations (tempeh).

Yeasts: Classified into the same group as molds, most do not live in soil but are instead found in environments with high sugar content such as the nectar of flowers or the surface of fruits.

Ascomycota:

4. **Debaromyces** – One of the most prevalent genera in dairy products. D hansenii is an important food spoilage species, it can grow in 24% NaCL and at aw as low as 0.65.
5. **Saccharomyces** – Includes the important industrial species, S. cerevisiae, used in bread and alcoholic fermentations. S. bailli is another important species because it is involved in the spoilage of several types of foods and is resistant to the antifungal preservatives benzoate and sorbate.
6. **Deuteromycota:**
   Candida – Includes the pathogen C. albicans, this genus also includes the most common species of yeasts in fresh ground beef & poultry, a few species are involved in industrial fermentations.

3.5.2 Production of molds

To multiply and grow a mold needs supply of some form of organic carbon for energy, a source of nitrogen for protein and vitamin synthesis, and several minerals.

Unlike lactic acid bacteria and yeast mold is usually not produced in fermentors with liquid media, but on solid media like agar, rice, cereal, breadcrumbs etc. as the mold sporulates more easily on a solid surface. A large surface area, an oxygen atmosphere, controlled temperatures and humidity as well as strict hygiene conditions are equally important for

3.5.3 Molds in food production

1. Cheese making

Three main types of cheese rely on molds for their characteristic properties: blue cheese, soft ripened cheese and rind-washed cheese.

To make blue cheese, the cheese is treated with a mold, usually Penicillium roqueforti, while it is still in the loosely pressed curd form. As the cheese matures, the mold grows, creating blue veins within it which gives the cheese its characteristic flavour. Examples include Stilton, Roquefort and Gorgonzola.

Soft ripened cheese such as Brie and Camembert are made by allowing Penicillium camemberti to grow on the outside of the cheese, which causes them to age from the outside in. The mold forms a soft white crust, and the interior becomes runny with a strong flavour.

Rind washed cheeses like Limburger also ripen inwards, but here, as the name suggests, they are washed with brine and other ingredients like beer and wine which contain mold. This also makes them attractive to bacteria, which add to the flavour.

2. Meat fermentation

A wide variety of molds (i.e. Penicillium chrysogenum and Penicillium nalgiovense) are used to ripen surfaces of sausages. The mold cultures plays a role in aroma formation and improve the texture of the sausages. They also contribute to shortening of the ripening period and preserving the natural quality and in that way expanding the shelf life of the meat product.

3. Soy sauce

Traditional soy sauce is made by mixing soybeans and other grains with a mold – either Aspergillus oryzae or Aspergillus sojae – and yeast. Historically, this would have been left to ferment in the sun, but nowadays it is mostly made under industrial conditions. The key flavour ingredients formed in this process are salts of the amino acid glutamic acid, notably monosodium glutamate.

4. Let’s understand molds- their good and bad aspects

Molds (or mildew) are fungi. Fungi are neither plant nor animal but, since 1969, have their own kingdom.

The fungi kingdom includes such wonderful organisms as the delicious edible mushrooms, the makers of the “miracle drug” penicillin and the yeast that makes our bread rise and our fine wines ferment. Biologically, all fungi have defined cell walls, lack chlorophyll and reproduce by means of spores.

Approximately 100,000 species of fungi have been described and it is estimated that there are at least that many waiting to be discovered. The vast majority of fungi feed on dead or decaying organic matter – they are one of the principle agents responsible for the natural recycling of dead plant and animal life.

Mold begins life as a spore (comparable to seeds in the plant kingdom). Spores are minuscule and are ever present in the air around us. Because of their size ranging from 3-40 microns (human hair is 100-150 microns), they are literally everywhere. In very humid air, the concentration of spores is much higher. Because of their tiny size, they are carried by air currents and only settle on surfaces in very still air. They may stay dormant for long periods of time, waiting for favorable conditions to germinate.

There are four critical requirements for mold growth – available mold spores, available mold food (organic substance), appropriate temperatures and considerable moisture.

3.5.4 The good and bad aspects of molds

Molds cause biodegradation of natural materials, which can be unwanted when it becomes food spoilage or damage to property. They also play important roles in biotechnology and food science in the production of various foods, beverages, antibiotics, pharmaceuticals and enzymes.

Some diseases of animals and humans can be caused by molds, usually as a result of allergic sensitivity to their spores or caused by toxic compounds produced by molds. The term “toxic mold” refers to molds that produce mycotoxins, such as Stachybotrys chartarum, and not to all molds in general. Symptoms caused by mold allergy are watery, itchy eyes, a chronic cough, headaches or migraines, difficulty breathing, rashes, tiredness, sinus problems, nasal blockage and frequent sneezing.

Common household molds have a characteristic “musty” or “earthy” smell, somewhat like the forest floor deep in the woods. Growing colonies of mold can also be visually observed in many cases. Most people are familiar with mold bread or mold growth on cheese or other food products that have been kept too long, so the “green fuzzy” characteristic of most mold growth is familiar.

Molds can also pose a hazard to human and animal health when they are consumed following the growth of certain mold species in stored food. Some species produce toxic secondary metabolites, collectively termed mycotoxins including aflatoxins, ochratoxins, fumonisins, trichotecenes, citrinin, and patulin.

3.5.5 How to prevent mold growth

Molds can grow almost everywhere and on any substance providing moisture is present. Thus, the best method of prevention is to reduce the amount of moisture.

Keep the relative humidity between 30% and 50%. To accomplish this goal, prevention measures include:

- ❖ Vent showers and other moisture generating sources directly to the outside.
- ❖ Control humidity with air conditioners and/or dehumidifiers (It is important to remember that when using air conditioners and dehumidifiers to keep them in good condition. Empty any water collectors regularly so this water does not contribute to the moisture problem! If you use humidifiers, ensure that they are cleaned regularly).
- ❖ Use exhaust fans when cooking, dishwashing, or laundering (especially in the food service or laundry areas) or when cleaning large areas.
- ❖ Insulate cold surfaces to prevent condensation on piping, windows, exterior walls, roofs and floors where possible
- ❖ Keep the building and the heating, ventilation and air conditioning (HVAC) systems in good repair.
- ❖ Clean up any floods or spills immediately (within 24-48 hours).
- ❖ For floors and carpets, remove spots or stains immediately. Reduce the amount of water used when cleaning carpets as much as possible.

- Do not install carpet around fountains, sinks, bathtubs/showers or directly on top of concrete floors that are prone to leaks or frequent condensation.

3.5.6 How Does Mold Grow on Food?

Mold spores are everywhere, and many strains grow on food. The spores anchor in bread, cheese, meat and fruit and grow into fruiting bodies that appear as dark, sometimes fuzzy blotches. Some benign strains, such as Penicillium roqueforti, which grows on blue cheese, are actually desirable, but others can cause allergic reactions. Some strains produce mycotoxins and aflatoxins, which can make you sick. Mold grows inside food as well as on the surface, so it isn't safe to simply cut it off. Unless you're making or storing cheese, it's best to discard moldy food.

3.5.7 Conditions for Mold Growth

Mold needs four things in order to grow: water, food, suitable air quality and temperature. Food that contains any kind of water or fluid is susceptible to mold growth. In addition, mold can only grow if it has food readily available to feed itself and grow. Mold is a fungus that feeds off of dead or dying organic matter, and can be destructive to your health and food quality. Mold will grow best in damp, dark and cool conditions, but can also grow in warmer temperatures as well. Mold grows best between 55 to 70 degrees Celsius.

3.5.8 How Mold Grows on Food

Tiny mold spores are all around us in the air, which is not harmful to our health in moderation. Once a spore lands on a surface, it searches for water and nutrients to feed off of. Food is able to grow mold easily because it is often kept in the perfect environment to foster mold growth. The temperature is usually about right, air quality is good, and the food itself provides the nutrients and water the mold needs in order to grow. As the spore takes root, it begins to spread and create more spores and spread quickly on the surface of your food. Some molds can take over your food in a matter of 12 to 24 hours, while others may take weeks.

3.5.9 Dangers of Mold on Food

Mold can be very dangerous if eaten. Mold is perhaps most common on bread, cheese, and fruits and vegetables left out in the kitchen. Eating mold on any item has the potential to make you very sick. Simply cutting off the moldy part does not render the food safe to eat. Mold has the ability to penetrate deep into the food and not just fester on the surface. If you do spot mold on your food, it is best to inspect the entire serving and not just one spot. In addition, if the food you are eating is part of a package of multiple servings, you should check all of them – mold can spread very quickly and infest an entire package of food.

3.5.10 Nine Molds Trying to Take over Your Kitchen

At some point in your life, you've likely rummaged around the kitchen for a tasty snack, opened it up, and discovered that your treat has been cheerfully consumed by a colorful fuzz. Although your reaction was probably simple— "Ick, mold!"—not all molds are made alike. There are actually a couple thousands of genera of mold within the kingdom Fungi, and many more species, each with its own special traits and talents.

Specialists, generalists, molds that like it damp, or dry, or fruity—they're living and breeding among us.

1. Rhizopus stolonifer, a.k.a. Black bread mold

It's likely that this white-then-black species is the one that took over your bagel. How? Hodge says spores may have landed on it back at the bakery, or maybe they first infiltrated some breadcrumbs that fell unnoticed behind your toaster. Rhizopus stolonifer is a bread specialist, getting to it early, eating it like crazy, and growing incredibly fast. Molds love sugar, "and as anyone on a low-carb diet knows, bread is starch, which is basically sugar and easy to break down," says Hodge. Is it safe to eat a Rhizopus-infected bagel? "It would taste disgusting, so don't go there.

2. Penicillium Chrysogenum

It's also possible that this puffy bluish mold is your bread-eating culprit. Yes, Penicillium is the same genus that brings you lifesaving penicillin. But don't try to use your blue bagel as a home remedy. "I can't tell you how many times people have said, 'I have a cut on my arm, should I put moldy bread on it?'" sighs Hodge. Mold only morphs into antibiotics after it's been extracted from its growth medium and purified in a lab and furthermore, the Pencillium group as a whole—there are over 300 species—is famous for making many and diverse toxins. Still, one species also makes blue cheese (Penicillium roqueforti), and another cures salami (Penicillium nalgiovense).

3. Wallemia Sebi

This is one of the true oddballs of the mold world—an extremophile that likes to live, as this name suggests, in extreme outposts. Extreme for a mold is a place that's salty or super-sugary, and therefore, dehydrating. Enter Wallemia sebi, thick brownish blobs of which Hodge once found floating in her maple syrup. "It's really slow and patient," she says, hiding out and waiting for its time to pounce. "So, if you eat your maple syrup at a normal rate, you're never going to see it." Wallemia sebi is the source of some amount of controversy among Hodge's colleagues. Some of them insist that it's harmless. But remember, Hodge points out, "it's been eating and excreting into your syrup. I highly recommend that people throw it out."

4. Zygophiala jamaicensis, a.k.a. Flyspeck

This mold is commonly found growing on apples (and grapes), and is also known as flyspeck. Confusingly, flyspeck can be caused by a variety of mold species, varying by region and type of apple. Flyspecked apples are usually snubbed by consumers, despite the fact that their little black bumps are harmless and grow only on the skin. "It's a hard life, being a plant," says Hodge. "Every one I can think of has multiple fungal problems." If you find flyspeck on your fruit at home, console yourself in the knowledge that it came in from the orchard and likely isn't lurking in your cupboards.

5. Fusarium Verticilliodes, a.k.a. Maize ear rot

Ever peeled open an ear of corn and found a patch of pink sliming the kernels? That's Fusarium verticilliodes, part of a huge genus that produces some truly terrible mycotoxins. It loooooves both the sweet corn you buy at the market and the field corn that's manufactured into corn chips and fake-meat patties. And it can survive processing to cause things

like estrogenic effects and immune suppression. Hence, Fusarium is highly regulated to try to keep it out of our food supply. And oh yeah, some species have also been used to make biological warfare agents.

6. Botrytis cinerea, a.k.a. Noble rot Fungus

Fluffy grey Botrytis cinerea will gladly sink its spores into the strawberries in your fruit bowl. It's not particularly toxic, says Hodge, but it can gobble up fruit with lightening speed. It comes in with your berries from the field, where damp conditions make it hard to eradicate. The upside: This mold species is also known as "noble rot." When it turns up (uninvited) on grapes in vineyards, it dries them out and concentrates their flavor; the grapes can then be used to make sweet wines like Sauternes (from France) and Tokaji Aszú (from Hungary and Slovakia).

7. Aspergillus Niger, a.k.a. Black mold

"This one is interesting," says Hodge. "It can grow on onions—it shows up as black flecks between the layers. And it can also cause ear infections in humans." But its talents don't end there; Aspergillus niger also causes you to exclaim, "Ooh, lemons," when you drink certain manufactured "lemony" beverages. ("No," corrects Hodge. "It's mold.") Niger's sister, Aspergillus oryzae, is used to make miso and soy sauce. And another, the parrot-green Aspergillus flavus, which favors peanuts and tree nuts, "is the worst fungus I can think of," says Hodge. Its crimes against humanity include causing liver cancer.

Check your progress - 3
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.
5. How to prevent mold growth?
6. Production of molds?

5. How to prevent mold growth?

Molds can grow almost everywhere and on any substance providing moisture is present. Thus, the best method of prevention is to reduce the amount of moisture.

Keep the relative humidity between 30% and 50%. To accomplish this goal, prevention measures include:

- Vent showers and other moisture generating sources directly to the outside.
- Control humidity with air conditioners and/or dehumidifiers (It is important to remember that when using air conditioners and dehumidifiers to keep them in good condition. Empty any water collectors regularly so this water does not contribute to the moisture problem! If you use humidifiers, ensure that they are cleaned regularly).
- Use exhaust fans when cooking, dishwashing, or laundering (especially in the food service or laundry areas) or when cleaning large areas.

- Insulate cold surfaces to prevent condensation on piping, windows, exterior walls, roofs and floors where possible.
- Keep the building and the heating, ventilation and air conditioning (HVAC) systems in good repair.
- Clean up any floods or spills immediately (within 24-48 hours).
- For floors and carpets, remove spots or stains immediately. Reduce the amount of water used when cleaning carpets as much as possible.
- Do not install carpet around fountains, sinks, bathtubs/showers or directly on top of concrete floors that are prone to leaks or frequent condensation.

6. Production of molds?

To multiply and grow a mold needs supply of some form of organic carbon for energy, a source of nitrogen for protein and vitamin synthesis, and several minerals.

Unlike lactic acid bacteria and yeast mold is usually not produced in fermentors with liquid media, but on solid media like agar, rice, cereal, breadcrumbs etc. as the mold sporulates more easily on a solid surface. A large surface area, an oxygen atmosphere, controlled temperatures and humidity as well as strict hygiene conditions are equally important for optimal growth.

3.6 LET US SUM UP

In this unit, we looked at the concept of Molds and the importance Morphology of Food Science. Then we studied about some of the important Physiology and Multiplication. The last part of the unit focused on recent concerns of Molds. Significance of Molds and Common Household molds in relation to Food science were highlighted in this section.

3.7 UNIT- END- EXERCISES

1. What are the characteristics of molds?
2. What is the structure of Mold?
3. What is Mold explain?
4. Can yeast turn into mold?
5. What is mold hyphae?
6. What are spores in Mold?
7. What is the difference between yeast and Mold?
8. What is food mold?
9. How can mold be helpful?
10. What does Mold mean in science?
11. What causes mold on fruit?

3.8 ANSWER TO CHECK YOUR PROGRESS

1. The term mold is used to describe certain multi cellular fungi consisting of a filamentous branching growth known as a mycelium.
2. Molds are classified as:

   a. Phycomycetes
   b. Ascomycetes
   c. Basidiomycetes
   d. Fungi IMperfecti
3. Molds in food production
   a. Cheese making
   b. Meat fermentation
   c. Soy sauce
   d. Let’s understand molds- their good and bad aspects

3.9 SUGGESTED READING

1. Banwart, G.J. (1979) Basic Food, Microbiology, AVI Publishing Co. Inc., Westport, Connecticut.
2. Frazier, w.e. and Westoff, D.C. (1996) Food Microbiology. Tata McGraw Hill Publishing Co. Ltd., New Delhi,pp 53°.
3. Peiczar, M. Jr., Chan, E.e.S. and Krieg, N.R. (1993) Microbiology, Tata McGrawHill Inc., New York, pp 918.
4. Stanier, R.Y.,Adelberg, E.A. and Ingraham, .J(1976) The microbial world. Prentice-Hall, Inc., Englewood Cliffs, N.J

UNIT IV – Viruses and Bacteriophages – discovery-morphology- Reproduction and its importance

4.1. Introduction
4.2. Objectives
4.3. Viruses and Bacteriophages
4.4. Discovery
4.5 Morphology
4.6 Reproduction and its importance
4.7 Let Us Sum Up
4.8 Unit- End- Exercises
4.9 Answer to check your Progress
4.10 Suggested Readings

4.1 INTRODUCTION

Till the presence of viruses was demonstrated by hvanowski in 1892, bacteria were considered the lowest forms of life. Viruses are called as 'obligate intracellular parasites', since they are unable to carry out any of the typical life functions until they are inside a host cell. Once inside the host cell, they thrive and direct the host cell to produce more viruses. As long as the virus is outside the host cell, it is known as 'vision'.

The viruses are minute when compared to bacteria. Except for a few, viruses like the cow pox virus, used in vaccination against small pox is 0.3 pm, whereas, the smallest type, like the foot and mouth disease virus is about 0.01 pm. Note, they are so small that they cannot be seen under an electron microscope.

The viruses consist of a protein layer, capsid, surrounding nucleic acid comprising either RNA or DNA. The important characteristic of viruses is that they are host- specific. Most viruses infect only one species, either animal or plant or else only very closely related species. The mammalian viruses do not affect any prant e.g. the polio virus infects humans and monkey and does not affect other animals, whereas, the tobacco mosaic virus, which attacks plants, does not affect humans.

Viruses are killed in a few minutes under pasteurization temperature i.e. 62°C for 30 minutes. They are affected by general disinfectants like phenols, formaldehyde, halogens and cresols. To a certain extent, soaps and detergents inactivate them and UV light destroys all viruses. They are not affected by antibiotics unlike bacteria.

4.2 OBJECTIVES

After going through the unit you will be able to;

- Describe the general characteristics of viruses as pathogens
- Describe viral genomes
- Describe the general characteristics of viral life cycles
- Differentiate among bacteriophages, plant viruses

- Describe the characteristics used to identify viruses as obligate intracellular parasites

4.3 VIRUSES

Viruses are the smallest obligate intracellular parasites that require living host cells in order to multiply and being alive. Viruses can infect any type of cell, ranging from human cells to protozoa.

4.3.1 What is Virus?

Viruses are small infectious agents that depend on living cells of other organisms for replication. They are composed of either RNA or DNA genome, which is surrounded by a virus-coded protein coat called capsid.

The protein components that form capsid are known as capsomers. This core viral structure namely nucleocapsid is sometimes surrounded by a membrane called envelop.

Some viral genome also encodes enzymes that are necessary for host cell infection. This entire viral structure with all necessary components is termed as virion.

4.3.2 Taxonomy of Virus

A universal taxonomic classification of viruses is carried out by the International Committee on Taxonomy of Viruses (ICTV). According to ICTV, the classification is as follows:

- Order – virales
- Family – viridae
- Subfamily – virinae
- Genus – virus
- Species – virus

4.3.3 Introduction to Viruses

Viruses are typically described as obligate intracellular parasites, acellular infectious agents that require the presence of a host cell in order to multiply. Viruses that have been found to infect all types of cells – humans, animals, plants, bacteria, yeast, archaea, protozoa…some scientists even claim they have found a virus that infects other viruses! But that is not going to happen without some cellular help.

4.3.4 Virus Characteristics

Viruses can be extremely simple in design, consisting of nucleic acid surrounded by a protein coat known as a capsid. The capsid is composed of smaller protein components referred to as capsomers. The capsid+genome combination is called a nucleocapsid.

Viruses can also possess additional components, with the most common being an additional membranous layer that surrounds the nucleocapsid, called an envelope. The envelope is actually acquired from the nuclear or plasma membrane of the infected host cell, and then modified with viral proteins called peplomers. Some viruses contain viral enzymes that are necessary for infection of a host cell and coded for within the viral genome. A complete virus, with all the components needed for host cell infection, is referred to as a virion.

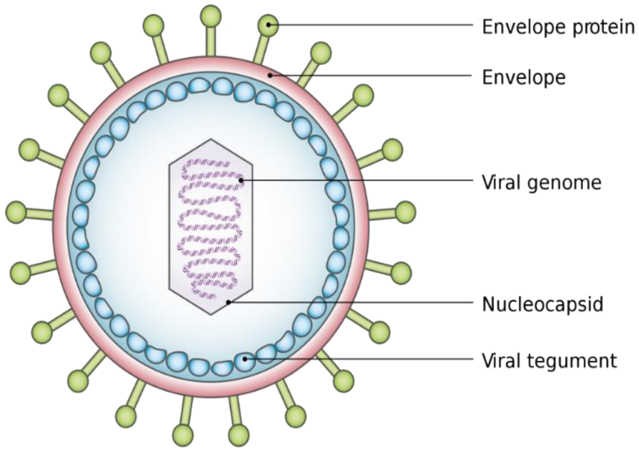


Fig. 4.3.1 Virus Characteristics, Image created by Ben Taylor

4.3.5 Virus Genome

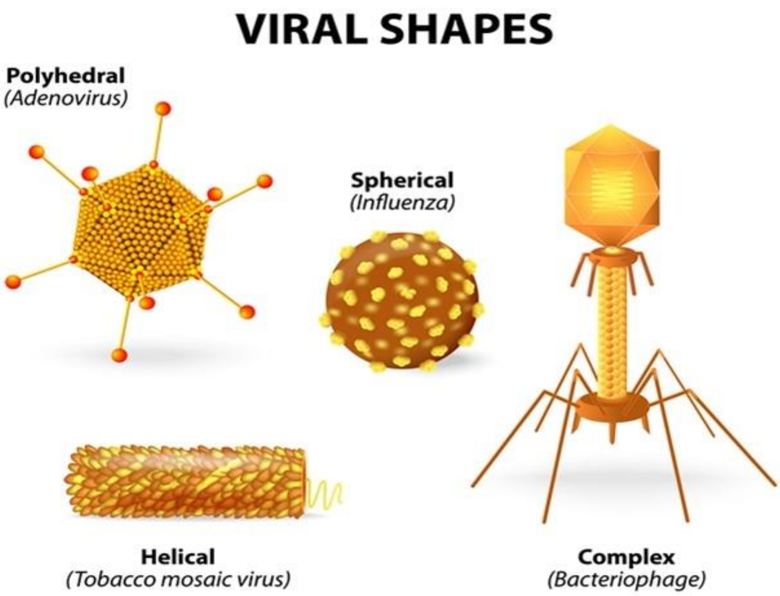
While cells contain double-stranded DNA for their genome, viruses are not limited to this form. While there are dsDNA viruses, there are also viruses with single-stranded DNA (ssDNA), double-stranded RNA (dsRNA), and single-stranded RNA (ssRNA). In this last category, the ssRNA can either positive-sense (+ssRNA, meaning it can transcribe a message, like mRNA) or it can be negative-sense (-ssRNA, indicating that it is complementary to mRNA). Some viruses even start with one form of nucleic acid in the nucleocapsid and then convert it to a different form during replication.

4.3.6 Virus Structure

According to the shape of viral nucleocapsid, there are two types of viruses: helical and icosahedral viruses. In case of helical viruses, capsomers are arranged helically around the viral genome, giving the virus an elongated tube-like structure.

In case of icosahedral viruses, icosahedral symmetry containing 20 equilateral triangular faces and 12 vertices gives the virus a spherical shape. Apart from these structures, some viruses including pox virus and bacteriophage possess completely different architecture, and thus, grouped as complex viruses.

Fig. 4.3.2 Vector illustration showing that there are many different



shapes and sizes of viruses. Image Credit: Designua / Shutterstock

4.3.7 Viral Infections

Viruses can be spread through various ways, such as inhalation, swallowing, insect bites, sexual transmission, and contaminated blood transfusion. The most common outcome of a viral infection is host cell death (virulent infection).

In contrast, some viruses can stay inside the host cell for years without causing any harmful effect (latent infection). In addition, viruses that undergo budding are released one at a time, causing persistent infection.

While the replication cycle of viruses can vary from virus to virus, there is a general pattern that can be described, consisting of five steps:

- ❖ Attachment – the virion attaches to the correct host cell.
- ❖ Penetration or Viral Entry – the virus or viral nucleic acid gains entrance into the cell.
- ❖ Synthesis – the viral proteins and nucleic acid copies are manufactured by the cells' machinery.
- ❖ Assembly – viruses are produced from the viral components.
- ❖ Release – newly formed virions are released from the cell.

1. **Attachment**

Outside of their host cell, viruses are inert or metabolically inactive. Therefore, the encounter of a virion to an appropriate host cell is a random event. The attachment itself is highly specific, between molecules on the outside of the virus and receptors on the host cell surface. This accounts for the specificity of viruses to only infect particular cell types or particular hosts.

2. **Penetration or Viral Entry**

Many unenveloped (or naked) viruses inject their nucleic acid into the host cell, leaving an empty capsid on the outside. This process is termed penetration and is common with bacteriophage, the viruses that infect bacteria. With the eukaryotic viruses, it is more likely for the entire capsid to gain entrance into the cell, with the capsid being removed in the cytoplasm. An unenveloped eukaryotic virus often gains entry via endocytosis, where the host cell is compelled to engulf the capsid resulting in an endocytic vesicle. An enveloped eukaryotic virus gains entrance for its nucleocapsid when the viral envelope fuses with the host cell membrane, pushing the nucleocapsid past the cell membrane. If the entire nucleocapsid is brought into the cell then there is an uncoating process to strip away the capsid and release the viral genome

3. **Synthesis**

The synthesis stage is largely dictated by the type of viral genome, since genomes that differ from the cell's dsDNA genome can involve intricate viral strategies for genome replication and protein synthesis. Viral specific enzymes, such as RNA-dependent RNA polymerases, might be necessary for the replication process to proceed. Protein production is

tightly controlled, to insure that components are made at the right time in viral development.

4. **Assembly**

The complexity of viral assembly depends upon the virus being made. The simplest virus has a capsid composed of 3 different types of proteins, which self-assembles with little difficulty. The most complex virus is composed of over 60 different proteins, which must all come together in a specific order. These viruses often employ multiple assembly lines to create the different viral structures and then utilize scaffolding proteins to put all the viral components together in an organized fashion.

5. **Release**

The majority of viruses lyse their host cell at the end of replication, allowing all the newly formed virions to be released to the environment. Another possibility, common for enveloped viruses, is budding, where one virus is released from the cell at a time. The cell membrane is modified by the insertion of viral proteins, with the nucleocapsid pushing out through this modified portion of the membrane, allowing it to acquire an en

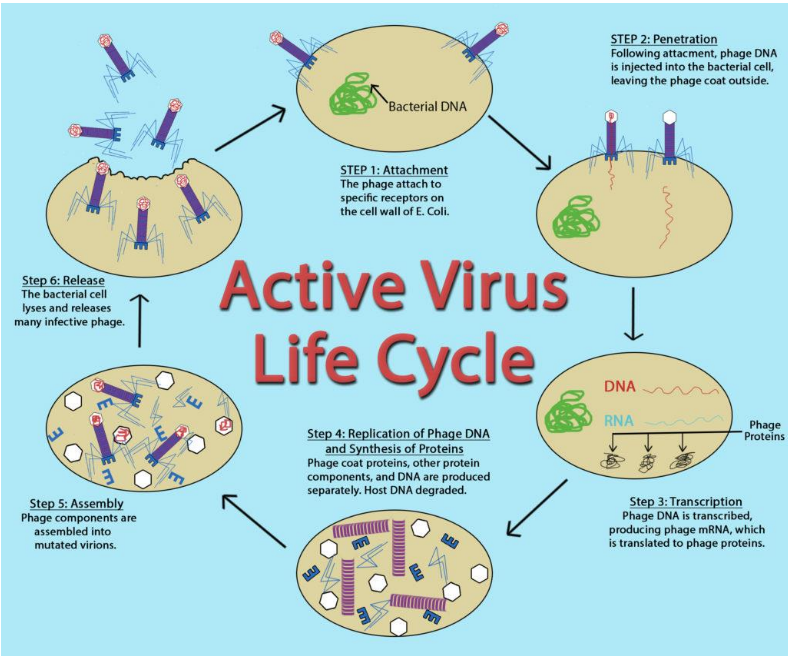


Fig. 4.3.3 Active Virus Life Cycle by John Kellogg Via OER at Oregon State University

4.3.9 Structure and Classification of Viruses

1. Structure and Function

Viruses are small obligate intracellular parasites, which by definition contain either a RNA or DNA genome surrounded by a protective, virus-coded protein coat. Viruses may be viewed as mobile genetic elements, most probably of cellular origin and characterized by a long co-evolution of virus and host. For propagation viruses depend on specialized host cells supplying the complex metabolic and biosynthetic machinery of eukaryotic or prokaryotic cells. A complete virus particle is called a virion. The main function of the virion is to deliver its DNA or RNA genome into the host cell so that the genome can be expressed (transcribed and translated) by the host cell. The viral genome, often with

associated basic proteins, is packaged inside a symmetric protein capsid. The nucleic acid-associated protein, called nucleoprotein, together with the genome, forms the nucleocapsid. In enveloped viruses, the nucleocapsid is surrounded by a lipid bilayer derived from the modified host cell membrane and studded with an outer layer of virus envelope glycoproteins.

4.3.10 Classification of Viruses

1. Morphology:

Viruses are grouped on the basis of size and shape, chemical composition and structure of the genome, and mode of replication. Helical morphology is seen in nucleocapsids of many filamentous and pleomorphic viruses. Helical nucleocapsids consist of a helical array of capsid proteins (protomers) wrapped around a helical filament of nucleic acid. Icosahedral morphology is characteristic of the nucleocapsids of many “spherical” viruses. The number and arrangement of the capsomeres (morphologic subunits of the icosahedron) are useful in identification and classification. Many viruses also have an outer envelope.

2. Chemical Composition and Mode of Replication:

The genome of a virus may consist of DNA or RNA, which may be single stranded (ss) or double stranded (ds), linear or circular. The entire genome may occupy either one nucleic acid molecule (monopartite genome) or several nucleic acid segments (multipartite genome). The different types of genome necessitate different replication strategies.

3. Nomenclature

Aside from physical data, genome structure and mode of replication are criteria applied in the classification and nomenclature of viruses, including the chemical composition and configuration of the nucleic acid, whether the genome is monopartite or multipartite. The genomic RNA strand of single-stranded RNA viruses is called sense (positive sense, plus sense) in orientation if it can serve as mRNA, and antisense (negative sense, minus sense) if a complementary strand synthesized by a viral RNA transcriptase serves as mRNA. Also considered in viral classification is the site of capsid assembly and, in enveloped viruses, the site of envelopment.

4.3.11 Classification and Taxonomy of Viruses

Although viruses are not classified in the three domains of life, their numbers are great enough to require classification. Since 1971, the International Union of Microbiological Societies Virology Division has given the task of developing, refining, and maintaining a universal virus taxonomy to the International Committee on Taxonomy of Viruses (ICTV). Since viruses can mutate so quickly, it can be difficult to classify them into a genus and a species epithet using the binomial nomenclature system. Thus, the ICTV’s viral nomenclature system classifies viruses into families and genera based on viral genetics, chemistry, morphology, and mechanism of multiplication. To date, the ICTV has classified known viruses in seven orders, 96 families, and 350 genera. Viral family names end in –viridae (e.g, Parvoviridae) and genus names end in −virus (e.g., Parvovirus). The names of viral orders, families, and genera are all italicized. When referring to a viral species, we often use a genus and species epithet such as Pandoravirus dulcis or Pandoravirus salinus.

4.3.12 Classification of Viral Diseases

While the ICTV has been tasked with the biological classification of viruses, it has also played an important role in the classification of diseases caused by viruses. To facilitate the tracking of virus-related human diseases, the ICTV has created classifications that link to the International Classification of Diseases (ICD), the standard taxonomy of disease that is maintained and updated by the World Health Organization (WHO). The ICD assigns an alphanumeric code of up to six characters to every type of viral infection, as well as all other types of diseases, medical conditions, and causes of death. This ICD code is used in conjunction with two other coding systems (the Current Procedural Terminology, and the Healthcare Common Procedure Coding System) to categorize patient conditions for treatment and insurance reimbursement

heck your progress -1
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.
1. What is viruses Genome?
2. To Explain the viral infections?
3. Write the viral replications?

1. What is viruses Genome?

While cells contain double-stranded DNA for their genome, viruses are not limited to this form. While there are dsDNA viruses, there are also viruses with single-stranded DNA (ssDNA), double-stranded RNA (dsRNA), and single-stranded RNA (ssRNA). In this last category, the ssRNA can either positive-sense (+ssRNA, meaning it can transcribe a message, like mRNA) or it can be negative-sense (-ssRNA, indicating that it is complementary to mRNA). Some viruses even start with one form of nucleic acid in the nucleocapsid and then convert it to a different form during replication.

2. To explain the viral infections?

Viruses can be spread through various ways, such as inhalation, swallowing, insect bites, sexual transmission, and contaminated blood transfusion. The most common outcome of a viral infection is host cell death (virulent infection).

In contrast, some viruses can stay inside the host cell for years without causing any harmful effect (latent infection). In addition, viruses that undergo budding are released one at a time, causing persistent infection.

3. Write the viral replications?

Viral replication is a multistep process that involves highly specific interaction between virus and host cell. Outside host cells, viruses are metabolically inactive and cannot replicate.

The replication process initiates by binding of specific components present on the outer surface of virus with cell surface receptors of the host. This process is called attachment.

In the next step, either entire virus or viral genome enters into the host cell through penetration. In case of naked or unenveloped viruses, mostly viral genome enters the cell and capsid is kept outside.

In contrast, most of the eukaryotic viruses inject the whole capsid into the host cells, and capsid is subsequently separated from the genome in the cytoplasm.

In case of unenveloped eukaryotic viruses, endocytosis is a frequently used process for capsid entry. However, enveloped eukaryotic viruses generally enter the host cell through fusion between viral envelop and host cell membrane.

Once inside, viruses use host cell's replication machinery to replicate its own genome. This process differs between different viruses depending on the viral genetic material.

Viral genome that is different from host's double-stranded DNA genome can undertake various strategies to continue replication and protein synthesis.

In this context, specific viral enzymes, including RNA-dependent RNA polymerase, play a vital role. After replication and protein synthesis, all viral components should be assembled in an organized manner.

This process is less complex in case of simple viruses containing only three kinds of proteins; whereas, complex viruses that contain as many as 60 proteins must undergo multiple complex steps.

Once properly assembled, newly formed virions are released from the host cell by two different mechanisms: cell lysis or budding. In case of cell lysis, virus components burst out the host cell and destroy it.

Once released, virions are ready to infect new host cells using the same procedure. Budding is more common among enveloped viruses. In this process, newly formed virions are released from the host cell one at a time.

Mechanistically, a virion modifies host's plasma membrane by inserting its proteins and entire capsid then pushes out through this modified portion, turning the plasma membrane into a viral envelop.

4.4 BACTERIOPHAGES

Bacteriophages, also known as phages, are viruses that infect and replicate only in bacterial cells. They are ubiquitous in the environment and are recognized as the most abundant biological agent on earth. They are extremely diverse in size, morphology, and genomic organization. However, all consist of a nucleic acid genome encased in a shell of phage-encoded capsid proteins, which protect the genetic material and mediate its delivery into the next host cell. Electron microscopy has allowed the detailed visualization of hundreds of phage types, some of which appear to have "heads," "legs," and "tails." Despite this appearance, phages are non-motile and depend upon a Brownian motion to reach their targets.

Like all viruses, bacteriophages are very species-specific with regard to their hosts and usually only infect a single, bacterial species, or even specific strains within a species. Once a bacteriophage attaches to a

susceptible host, it pursues one of two replication strategies: lytic or lysogenic. During a lytic replication cycle, a phage attaches to a susceptible host bacterium, introduces its genome into the host cell cytoplasm, and utilizes the ribosomes of the host to manufacture its proteins. The host cell resources are rapidly converted to viral genomes and capsid proteins, which assemble into multiple copies of the original phage. As the host cell dies, it is either actively or passively lysed, releasing the new bacteriophage to infect another host cell. In the lysogenic replication cycle, the phage also attaches to a susceptible host bacterium and introduces its genome into the host cell cytoplasm. However, the phage genome is instead integrated into the bacterial cell chromosome or maintained as an episomal element where, in both cases, it is replicated and passed on to daughter bacterial cells without killing them. Integrated phage genomes are termed prophages, and the bacteria containing them are termed lysogens. Prophages can convert back to a lytic replication cycle and kill their host, most often in response to changing environmental conditions.

4.4.1 Why do we need to study bacteriophages?

The first serious research of phages was done by d'Herelle which inspired him to do first experiments using phages in medicine. D'Herelle has used phages to treat a boy who had bad disentheria (d'Herelle, 1917). After administration of phages the boy successfully recovered. Later d'Herelle and scientists from Georgia (former USSR) have created an Institute to study the properties of bacteriophages and their use in treating bacterial infections a decade before the discovery of penicillin. Unfortunately a lack of knowledge on basic phage biology and their molecular organisation has led to some clinical failures. At the end of 1930s antibiotics were discovered; they were very effective, and nearly wiped out studies on the medical use of phages. However, a new problem of bacterial resistance to antibiotics has arisen after many years of using them. Bacteria adapted themselves to become resistant to the most potent drugs used in modern medicine.

The emergence of modified pathogens such as Mycobacterium tuberculosis, Enterococcus faecalis, Staphylococcus aureus, Acinetobacter baumannii and Pseudomonas aeruginosa, and methicillin-resistant S. aureus (MRSA) has created massive problems in treating patients in hospitals (Coelho et al., 2004, Hanlon, 2007; Burrowes et al., 2011) and the time required to produce new antibiotics is much longer than the time of bacterial adaptation. Modern studies on the phage life cycle have revealed a way for their penetration through membrane barriers of cells. These results are important in the development of methods for using bacteriophages as a therapeutic option in the treatment of bacterial infections (Brussow & Kutter, 2005). Phages, like many other viruses, infect only a certain range of bacteria that have the appropriate receptors in the outer membrane.

4.4.2 Classification of bacteriophages

All known phages can be divided in two groups according to the type of infection. One group is characterized by a lytic infection and the other is represented by a lysogenic, or temperate, type of infection (Figure

1). In the first form of infection the release of DNA induces switching of the protein machinery of the host bacterium for the benefit of infectious agents to produce 50-200 new phages. To make so many new phages requires nearly all the resources of the cell, which becomes weak and bursts. In other words, lysis takes place, causing death of the host bacterial cell. As result new phages are released into the extracellular space. The other mode of infection, lysogenic, is characterized by integration of the phage DNA into the host cell genome, although it may also exist as a plasmid. Incorporated phage DNA will be replicated along with the host bacteria genome and new bacteria will inherit the viral DNA. Such transition of viral DNA could take place through several generations of bacterium without major metabolic consequences for it. Eventually the phage genes, at certain conditions impeding the bacterium state, will revert to the lytic cycle, leading to release of fully assembled phages (Figure 4.4.1). Analysis of phages with lysogenic or lytic mode of infection has shown that there is a tremendous variety of bacteriophages with variations in properties for each type of infection. Moreover, under certain conditions, some species were able to change the mode of infection, especially if the number of host cells was falling down. Temperate phages are not suitable for the phage therapy.

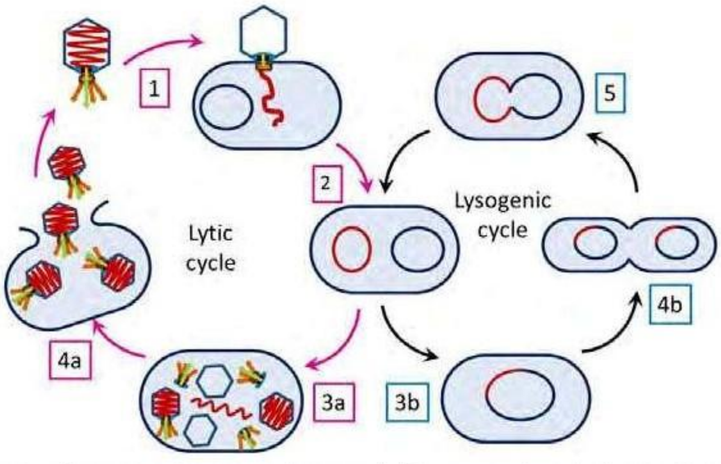


Fig. 4.4.1 Two cycles of bacteriophage reproduction.
1 - Phage attaches the host cell and injects DNA; 2 – Phage DNA enters lytic or lysogenic cycle; 3a – New phage DNA and proteins are synthesised and virions are assembled; 4a –Cell lyses releasing virions; 3b and 4b – steps of
lysogenic cycle: integration of the phage genome within the bacterial chromosome (becomes prophage) with normal bacterial reproduction; 5- Under certain conditions the prophage excises from the bacterial chromosome and initiates the lytic cycle. (Copyright of E.V. Orlova)

Classification of viruses is based on several factors such as their host preference, viral morphology, genome type and auxiliary structures such as tails or envelopes. The most upto-date classification of bacteriophages is given by Ackermann (2006). The key classification factors are phage morphology and nucleic acid properties. The genome can be represented by either DNA or RNA. The vast majority of phages

contain double strand DNA (dsDNA), while there are small phage groups with ssRNA, dsRNA, or ssDNA (ss stands for single strand). There are a few morphological groups of phages: filamentous phages, isosahedral phages without tails, phages with tails, and even several phages with a lipid-containing envelope or contain lipids in the particle shell. This makes bacteriophages the largest viral group in nature. At present, more than 5500 bacterial viruses have been examined in the electron microscope (Ackermann, 2007) (Figure 4.4.2).

Pleomorphic and filamentous phages comprise ~190 known bacteriophages (3.6% of phages) and are classified into 10 small families (Ackermann, 2004). These phages differ significantly in their features and characteristics apparently representing different lines of origin. Pleomorphic phages are characterized by a small number of known members that are divided into three

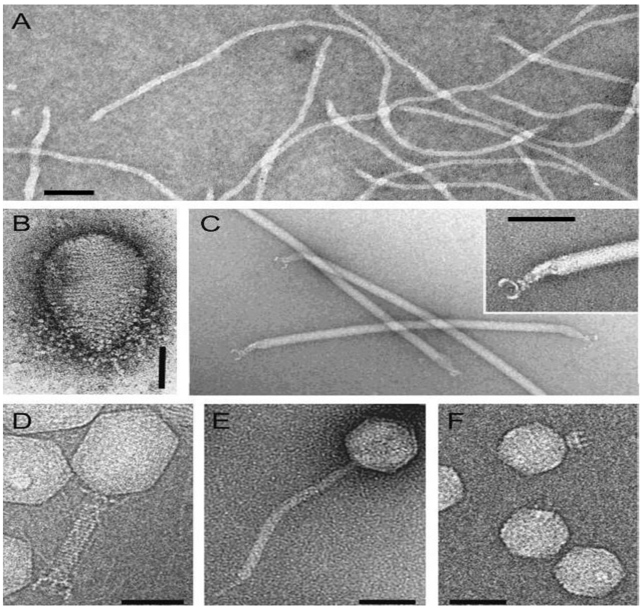


Fig. 4.4.2 Images of bacteriophages

A – filamentous phage B5 (Inoviridae) infects Propionibacterium freudenreichi; negatively stained with 2% uranyl acetate (UA) (Chopin et al., 2002, reproduced with permission of M.C. Chopin); B - Sulfolobus neozealandicus dropletshaped virus (Guttaviridae) of the crenarchaeotal archaeon Sulfolobus, negatively stained by 2% UA (Arnold et al., 2000, reproduced with permission of W. Zillig); C - Acidianus filamentous virus 1 (Lipothrixviridae) with tail structures in their native conformation, negatively stained with 3% UA (Bettstetter et al., 2003, reproduced with permission of D. Prangishvili); D – Bacteriophage T4 (Myoviridae), in vitreous ice (Rossmann et al., 2004, reproduced with permission of M.G. Rossman); E – Bacteriophage SPP1 (Siphoviridae), negative stain 2% UA (Lurz et al., 2001, reproduced with permission of R. Lurz); F - Bacteriophage P22 (Podoviridae) in vitreous ice (Chang et al., 2006, reproduced with permission of W. Chiu). Bars are 50 nm families that need further characterization. Plasmaviridae (dsDNA) includes phages with dsDNA that are covered by a lipoprotein envelope and therefore can be called a nucleoprotein granule. Members of the Fusseloviridae family have dsDNA inside a lemon-shaped capsid with short spikes at one end;

Guttavirus phage group (dsDNA) is represented by droplet-shaped virus-like particles, Arnold et al., 2000).

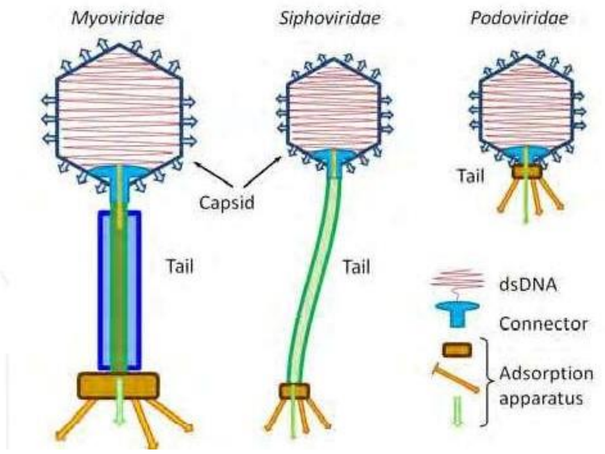


Fig. 4.4.3 Tailed phage families (copyright of E.V. Orlova).

The tailed phages were classified into the order Caudavirales (dsDNA) (Figure 4.4.3) (Ackermann, 2006). Tailed phages can be found everywhere and represent 96% of known phages and are separated into three main phylogenetically related families. Tailed phages are divided into three families: A - Myoviridae with contractile tails consisting of a sheath and a central tube (25% of tailed phages); B - Siphoviridae , long, noncontractile tails (61%); C - Podoviridae , short tails (14 %). Since the tailed phages represent the biggest population of bacteriophages they are easy to find and purify; they are the most studied family both biochemically and structurally. For this reason the following part of the review will concentrate on results and analysis of the tailed bacteriophages.

4.4.3 Differentiation of bacteriophages on the basis of their life cycle

The differentiation between phages on the basis of their type of genetic material is a rather technical one. Another important differentiation can be made on the basis of the phage life cycle.

Two main groups are distinguished there

- ❖ Lysogenic or temperate phages
- ❖ Lytic phages

1. Lysogenic phages

The most important feature of lysogenic phages is the integration of their genome in the bacterial genome after infection. This results in the so-called pro-phage stage. Genes that control the lytic pathway are repressed by protein repressors which bind to specific DNA-regions. This prevents transcription of genes whose products are involved in the lytic pathway. During this stage the bacteria grows and divides normally and the phage inside the bacteria can remain unnoticed. Upon activation of the pro-phage, in many cases for as yet unknown reasons, the bacteriophages' genetic material is transcribed and replicated inside the bacterium. This ultimately results in the formation of new bacteriophage particles which, once released form the bacterium, are capable of infecting new bacteria and

integration of their genetic material into the bacterial genome, thus closing the circle.

Although highly interesting, lysogenic phages are (as yet) unpredictable in their properties and behaviour. Transition from the pro-phage stage to the lytic phage is uncontrollable and the exchange of genetic material unpredictable. Lysogenic phages have been observed to transfer potentially harmful genes into their target bacteria (including genes encoding Shiga toxins of Shigatoxinogenic E. coli (Tóth et al., 2003) the cholera toxin of toxinogenic Vibrio cholera (Campos et al., 2003) and various antibiotic resistance genes (Schmieger & Schicklmaier, 1999). Although many of the lysogenic phages are relatively well studied (e.g. Phage λ) and sometimes detailed knowledge is available about their genome and its regulation, because of their unpredictable behaviour, they are generally considered to be unsuitable of use in bacteriophage therapy. For this reason they will not be discussed in this report.

2. **Lytic phages**

Lytic phages infect their host, replicate and then kill their host by cell lysis, thereby releasing progeny viruses into the environment. Infection of the bacterial host is often based on specific recognition of particular components on the pili or cell wall of the bacterium which is likely to determine the specific recognition. After initial infection it can be a matter of hours before cell lysis occurs.

Lytic phages are theoretically ideally suited as an alternative antibiotic in phage therapy:

- Most bacteriophages are very specific for their host bacterium.
- Upon successful infection they replicate exponentially.
- They kill their hosts quickly (often in hours)
- Upon bacterial lysis a large number of progeny phages are released into the environment.
- Each of those phages is capable of infecting other target bacteria. As an 'antibiotic' bacteriophages are 'self multiplying'.
- Bacteriophages depend on their hosts and will disappear with the destruction of their target
- bacterium leaving no residues; 'antibiotic' bacteriophages are 'self eliminating'.

4.4.4 Clinical Significance

Phages are clinically significant for several reasons. First, many highly pathogenic bacterial toxins are encoded by bacteriophage genomes, such that the host bacterium is only pathogenic when lysogenized by the toxin-encoding phage. Examples are cholera toxin in Vibrio cholerae, diphtheria toxin in Corynebacterium diphtheriae, botulinum neurotoxin in Clostridium botulinum, the binary toxin of Clostridium difficile, and Shiga toxin of Shigella species. Without their phage-encoded toxins, these bacterial species are either much less pathogenic or not pathogenic at all. Why phages encode these toxins is not known. While cholera toxin arguably helps both the phage and its host reach their next victim by inducing copious, watery diarrhea, the paralysis resulting from botulinum toxin would seem to have the opposite effect.

A third clinically relevant aspect of bacteriophages is that their detection can be used as a biomarker for the presence of their

host in a complex environmental sample. This most commonly is used as a surrogate for fecal contamination of water sources. If the phage is present, the host most likely is as well. Alternatively, phages have been engineered to produce a detectable molecule, such as luciferase, when they infect their host as a means to detect bacteria in a mixed environmental sample.

While mostly supplanted by newer technologies, bacteriophages also are clinically relevant for their ability to distinguish strains of the same bacterial species. Most species of bacteria studied have multiple bacteriophage pathogens, just as humans as a species are susceptible to multiple viruses. Different strains within a species are resistant to some phages and not others. By infecting each strain systematically with a standardized panel of phages for that species, each strain can be identified by the pattern of susceptibility and resistance to each phage type. Phage typing of Staphylococcus aureus, for example, utilized a standardized panel of bacteriophages shared internationally to differentiate strains of S. aureus. Before the development of molecular methods for this purpose, such as multilocus sequence typing and pulsed-field gel electrophoresis, phage typing was the criterion standard for tracking strains for epidemiological purposes.

4.4.5 Enhancing Healthcare Team Outcomes

Antibiotic Resistance and Infection Control

Bacteriophage are drivers of bacterial evolution in the human microbiome (Level II evidence). Prophage can be induced to switch to the lytic replication cycle by host cell stress, including antimicrobial drugs. Therefore, antibiotic treatments, especially those targeting gut microbial flora, can be expected to alter the viral (phage) microbiome as well. Bacteriophage are not as easily inactivated as vegetative bacterial cells, but they are vulnerable to UV inactivation, autoclaving, and standard hospital disinfection procedures.

3. **Bacterial Toxin Mediated Disease**

It is important for all team members caring for a patient with a phage-borne toxin-mediated disease, such as cholera or shigella, that disinfection procedures should be chosen for their ability to inactivate viruses as well as for bacteria. Even though the bacteriophage do not infect human cells directly, they can mediate virulence gene transfer from pathogenic to non-pathogenic bacterial strains.

Check your progress - 2
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.
4. What are the Bacteriophages called?
5. Clinical significant of bacteriophage?

4. What are the Bacteriophages called?

Bacteriophages, also known as phages, are viruses that infect and replicate only in bacterial cells. They are ubiquitous in the environment and are recognized as the most abundant biological agent on earth. They are extremely diverse in size, morphology, and genomic organization. However, all consist of a nucleic acid genome encased in a shell of phage-encoded capsid proteins, which protect the genetic material and mediate its delivery into the next host cell. Electron microscopy has allowed the detailed visualization of hundreds of phage types, some of which appear to have "heads," "legs," and "tails." Despite this appearance, phages are non-motile and depend upon a Brownian motion to reach their targets.

Like all viruses, bacteriophages are very species-specific with regard to their hosts and usually only infect a single, bacterial species, or even specific strains within a species. Once a bacteriophage attaches to a susceptible host, it pursues one of two replication strategies: lytic or lysogenic. During a lytic replication cycle, a phage attaches to a susceptible host bacterium, introduces its genome into the host cell cytoplasm, and utilizes the ribosomes of the host to manufacture its proteins. The host cell resources are rapidly converted to viral genomes and capsid proteins, which assemble into multiple copies of the original phage. As the host cell dies, it is either actively or passively lysed, releasing the new bacteriophage to infect another host cell. In the lysogenic replication cycle, the phage also attaches to a susceptible host bacterium and introduces its genome into the host cell cytoplasm. However, the phage genome is instead integrated into the bacterial cell chromosome or maintained as an episomal element where, in both cases, it is replicated and passed on to daughter bacterial cells without killing them. Integrated phage genomes are termed prophages, and the bacteria containing them are termed lysogens. Prophages can convert back to a lytic replication cycle and kill their host, most often in response to changing environmental conditions.

5. Clinical significant of bacteriophage?

Phages are clinically significant for several reasons. First, many highly pathogenic bacterial toxins are encoded by bacteriophage genomes, such that the host bacterium is only pathogenic when lysogenized by the toxin-encoding phage. Examples are cholera toxin in Vibrio cholerae, diphtheria toxin in Corynebacterium diphtheriae, botulinum neurotoxin in Clostridium botulinum, the binary toxin of Clostridium difficile, and Shiga toxin of Shigella species. Without their phage-encoded toxins, these bacterial species are either much less pathogenic or not pathogenic at all. Why phages encode these toxins is not known. While cholera toxin arguably helps both the phage and its host reach their next victim by inducing copious, watery diarrhea, the paralysis resulting from botulinum toxin would seem to have the opposite effect.

Finally, bacteriophages were the first type of virus to be discovered and were a part of many of the fundamental discoveries of molecular biology. For example, the proof that DNA was the molecule that transmitted genetic information, the basic mechanisms of gene regulation, and the genetic code to name but a few, were all discovered using bacteriophages.

4.5 DISCOVERY OF BACTERIOPHAGES

Discovery of bacteriophages were discovered more than a century ago. In 1896, Ernest Hanbury Hankin, a British bacteriologist (1865 – 1939), reported that something in the waters of rivers in India had unexpected antibacterial properties against cholera and this water could pass through a very fine porcelain filter and keep this distinctive feature (Hankin, 1896). However, Hankin did not pursue this finding. In 1915, the British bacteriologist Frederick Twort (1877–1950), Superintendent of the Brown Institution of London, discovered a small agent that killed colonies of bacteria in growing cultures. He published the results but the subsequent work was interrupted by the beginning of World War I and shortage of funding. Felix d'Herelle (1873-1949) discovered the agent killing bacteria independently at the Pasteur Institute in France in 1917. He observed that cultures of the dysentery bacteria disappear with the addition of a bacteria-free filtrate obtained from sewage. D'Herelle has published his discovery of “an invisible, antagonistic microbe of the dysentery bacillus" (d'Herelle, 1917)

4.5.1 Growth of Bacteria

True growth is defined as an orderly increase in all cell constituents. However, microbial growth is measured in terms of increase in cell number.Most microorganisms, when added to food, multiply at a very rapid rate under favourable conditions. A single bacterial cell divides into two every 20 to 30 minutes. If the rate of multiplication is maintained, a single cell will produce one billion new cells after a period of 10 hours.

If the logarithms of the number of organisms per ml. and the time in hours is plotted on a graph, it is observed that the rate of multiplication is not maintained indefinitely, but four distinct phases of growth are observed as indicated in Fig. 1.12. To control bacterial growth we must first be familiar with these phases.

4.5.2 Growth Phases

1. The initial phase is called the lag phase during which there is no growth. The number of bacteria remains constant and the cells get adjusted to their new environment. Bacteria show an increase in size but not in number.
2. In the exponential growth phase or logarithmic growth phase, the rate of growth increases at a very rapid or logarithmic pace. In this phase the generation time is constant and the growth rate is the highest. .
3. In the stationary phase the rate of multiplication decreases gradually and average generation time increases. During this phase the number of living bacteria remains constant due to the death of some bacteria and the rate of growth equals the rate of death. They may die from lack of nourishment.
4. In the death phase the number of living bacteria declines rapidly at the same rate at which they grew. The number of surviving cells

taper off very gradually. The more vulnerable cells die first and the resistant forms remain for some months or even years. They die because of a change in the environment such as,

I. exhaustion of nutrients,
II. accumulation of toxic metabolic waste products, or
III. alteration of pH, etc.

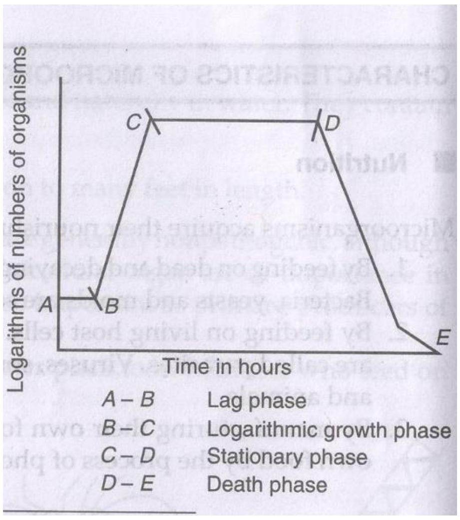


Fig.4.5.1 Four Phases of Microbial Growth

> **Check your progress - 3**
> **Notes: a) Write your answers in the space given below.**
> **b) Compare your answers with those given at the end of the unit.**
> 6. To measure the Bacterial growth?

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True growth is defined as an orderly increase in all cell constituents. However, microbial growth is measured in terms of increase in cell number.

The time period which lapses between two successive cell divisions is called generation time. II varies in different organisms.'The environmental conditions available also determine the time required for cell

Most microorganisms, when added to food, multiply at a very rapid rate under favourable conditions. A single bacterial cell divides into two every 20 to 30 minutes. If the rate of multiplication is maintained, a single cell will produce one billion new cells after a period of 10 hours.

4.6 MORPHOLOGY- REPRODUCTION AND ITS IMPORTANCE

The morphology of the bacteriophages has been best studied by electron microscopy. It is tadpole-shaped with polyhedral head, a short neck and collar and a straight tail. The head is bipyramidal hexagonal in

shape and measures 950 x 650 Å. The contents of head are enclosed by a membrane (capsid) about 35 Å thick.

The capsid is made up of about 2000 capsomeres (proteins) and each protein subunit has molecular weight of about 80,000. The head encloses a linear double stranded DNA, which contains more than 75 genes. The DNA remains greatly folded.

The tail is in the form of a hollow cylinder. It consists of a central hollow core surrounded by a spring-like contractile sheath. The sheath is formed of 144 subunits which are arranged in a hollow cylinder consisting of 24 rays of six subunits each. Through the central space of the core, the phage chromosome travels into the host cell.

In the lamda coliphage the head capsid is a regular icosahedron. In the coliphages T3 and T7 the tail is short and stubby. The coliphages T1 and T5 have no tail sheath and their fibres are rudimentary.

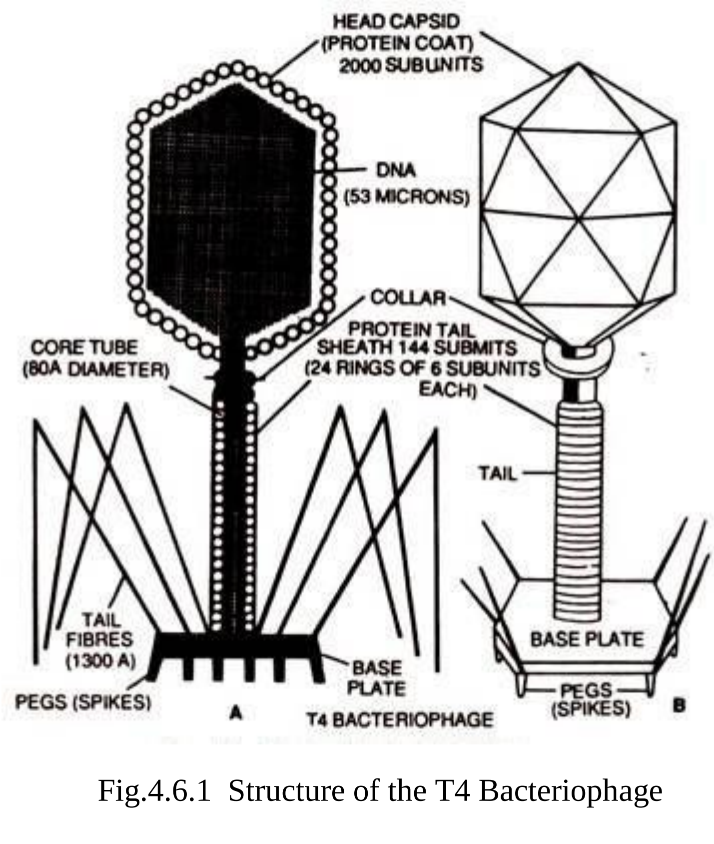


Fig.4.6.1 Structure of the T4 Bacteriophage

4.6.1 Chemistry of Bacteriophages:

Physical and chemical studies have established that the T – even phages are composed wholly of DNA and protein. DNA constitute 40% by weight and protein remaining 60%. DNA occurs within the head. Head membrane, sheath and tail fibres are composed of different proteins. In bacteriophage MS2, the genetic material is RNA instead of DNA.

Hershey and Chase (1952) labelled the protein by radioactive sulphur (35S) and DNA by radioactive phosphorus (32P) in T2 phage and established that the genetic material of the virus is its DNA and not the protein. This agrees with Avery, MacLeod and McCarty's discovery with Diplococcus pneumoniae, a bacterium.

4.6.2 Mode of Infection of Bacteriophage:

There are two types of bacterial infections:

Virulent infection and temperate infection.

1. Virulent Infection:

T-even phages (T2, T4 and T6) of Escherichia coli are examples. They multiply as soon as they enter the host cell, resulting in lysis or breakdown of host cell. Such viruses are called lytic viruses. The mode of infection is called virulent.

There are four steps in the life cycle of lytic bacterial viruses. They are Adsorption, Injection, Replication and Lysis.

(a) Adsorption:

At the time of infection, a bacteriophage becomes anchored to the bacterial wall by its tail fibres and tail spikes so that the tail and head are perpendicular to the surface.

(b) Injection:

Within a few minutes after attachment, the contractile sheath of the tail shortens, to less than half its original length. An enzyme of the core of

The tail digests part of the bacterial cell wall. It results in the production of a hole and finally, the phage DNA is injected into the bacterial cell. The capsid of phage remains outside the bacterial cell.

(c) Replication:

The bacterial DNA is disturbed; manufacture of bacterial protein stops and the viral genes takes over. Among the first proteins to be made are the enzymes needed for viral DNA replication. This happens within the first 5 minutes after break through. Three minutes later another set of genes directs the synthesis of structural proteins that will form the head components and tail component

The first completed virus particles appear 13 minutes after infection. This process continues for another 12 minutes until about 200 such particles have been completed and the raw materials of the bacterial cell have been virtually exhausted.

(d) Lysis:

A viral enzyme, a lysozyme, then appears and attacks the cell wall, liberating the new viral particles.

2. Temperate Infection:

The best studied temperate phage is the lamda phage of the bacterium E. coli. In this virus do not cause lysis of the host cell in the usual way. The viral chromosome becomes integrated with the host chromosome.

Detailed study on the life cycle of lamda phage indicate that on entering the host cell, the phage DNA has two options. It may immediately multiply and start lytic cycle (virulent infection) described earlier. But other times (lysogenic cycle), the viral chromosome becomes a part of the host chromosome and is called the prophage. When the viral DNA is incorporated into the host DNA it behaves like a gene on the genetic map of the host. It replicates along the host DNA.

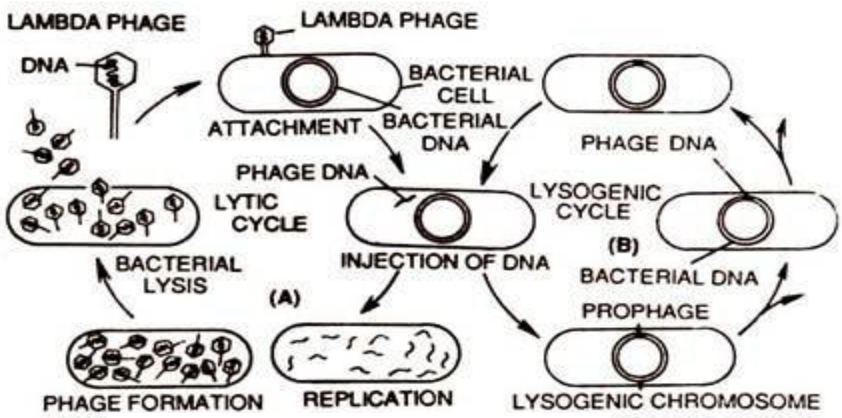


Fig.4.6.2 Life cycle of the lamda phage

Thus lamda phage exists in two forms, the virion and the provirus. The virion is the normal condition with a DNA core and a protein coat. The provirus is the intracellular form in which the viral DNA is a gene on the

DNA of the host. Bacteria containing prophage are called lysogenic bacteria. Viruses whose chromosomes becomes prophage are called lysogenic viruses.

4.6.3 Reproduction and its importance of Bacteriophage

Bacterial reproduction and sex are two separate processes. Bacteria reproduce by a process called binary fission. During binary fission, the DNA is replicated and the cell separates. Each daughter cell receives a complete genome. This process represents asexual reproduction, as no exchange or reassortment of genetic information takes place.

During sexual reproduction, genes are reshuffled to increase genetic diversity. Gene transfer in eukaryotes occurs when two germ line cells from parents merge to form a zygote. The zygote contains equal amounts of DNA from both parents. Gene transfer in bacteria is a one-way street in that a donor cell gives DNA to a recipient cell, but not vice versa.

Gene transfer between bacteria may occur by uptake of unprotected DNA, movement of DNA in virus particles, or cell-to-cell DNA transfer.

Bacterial gene transfer occurs by one of three mechanisms: transformation, transduction, and conjugation.

Transformation is the uptake of naked DNA from the environment. Transduction occurs via a bacteriophage. The bacteriophage acquires host cell genetic information during packaging and transfers this material to a new host cell during infection. Conjugation is the movement of genetic information from cell-to-cell.

DNA that enters a bacterial cell may survive on its own if it is a complete replicon. Otherwise, it will be degraded unless it is recombined into the host chromosome.

Incoming DNA for a bacterial cell faces three possible fates. First, the DNA may enter the cell and survive as a replicon, which means it is able to replicate independent of the host cell's chromosome, and therefore must possess an origin of replication. Second, the incoming DNA may be completely degraded. Third, some of the incoming DNA may be

recombined into the host chromosome, while the rest is degraded. Recombination usually only occurs between DNA molecules that share homology.

4.6.4 Bacterial Reproduction and Binary Fission

Bacteria are prokaryotic organisms that reproduce asexually. Bacterial reproduction most commonly occurs by a kind of cell division called binary fission. Binary fission involves the division of a single cell, which results in the formation of two cells that are genetically identical. In order to grasp the process of binary fission, it is helpful to understand bacterial cell structure.

4.6.5 Bacterial Cell Structure

Bacteria have varying cell shapes. The most common bacteria cell shapes are spherical, rod-shaped, and spiral. Bacterial cells typically contain the following structures: a cell wall, cell membrane, cytoplasm, ribosomes, plasmids, flagella, and a nucleoid region.

1. **Cell Wall:** An outer covering of the cell that protects the bacterial cell and gives it shape.
2. **Cytoplasm:** A gel-like substance composed mainly of water that also contains enzymes, salts, cell components, and various organic molecules.
3. **Cell Membrane or Plasma Membrane:** Surrounds the cell's cytoplasm and regulates the flow of substances in and out of the cell.
4. **Flagella:** Long, whip-like protrusion that aids in cellular locomotion.
5. **Ribosomes:** Cell structures responsible for protein production.
6. **Plasmids:** Gene carrying, circular DNA structures that are not involved in reproduction.
7. **Nucleoid Region:** Area of the cytoplasm that contains the single bacterial DNA molecule.

4.6.6 Binary Fission

Most bacteria, including Salmonella and E.coli, reproduce by binary fission. During this type of asexual reproduction, the single DNA molecule replicates and both copies attach, at different points, to the cell membrane. As the cell begins to grow and elongate, the distance between the two DNA molecules increases. Once the bacterium just about doubles its original size, the cell membrane begins to pinch inward at the center. Finally, a cell wall forms which separates the two DNA molecules and divides the original cell into two identical daughter cells.

4.6.7 Bacterial Recombination

Binary fission is an effective way for bacteria to reproduce, however, it is not without problems. Since the cells produced through this type of reproduction are identical, they are all susceptible to the same types of threats, such as environmental changes and antibiotics. These hazards could destroy an entire colony. In order to avoid such perils, bacteria can become more genetically varied through recombination. Recombination involves the transfer of genes between cells. Bacterial recombination is accomplished through conjugation, transformation, or transduction.

4.6.8 Conjugation

Some bacteria are capable of transferring pieces of their genes to other bacteria that they contact. During conjugation, one bacterium connects itself to another through a protein tube structure called a pilus. Genes are transferred from one bacterium to the other through this tube.

4.6.9 Transformation

Some bacteria are capable of taking up DNA from their environment. These DNA remnants most commonly come from dead bacterial cells. During transformation, the bacterium binds the DNA and Transports it across the bacterial cell membrane. The new DNA is then incorporated into the bacterial cell's DNA.

4.6.10Transduction

Transduction is a type of recombination that involves the exchange of bacterial DNA through bacteriophages. Bacteriophages are viruses that infect bacteria. There are two types of transduction: generalized and specialized transduction.

Once a bacteriophage attaches to a bacterium, it inserts its genome into the bacterium. The viral genome, enzymes, and viral components are then replicated and assembled within the host bacterium. Once formed, the new bacteriophages lyse or split open the bacterium, releasing the replicated viruses. During the assembling process, however, some of the host's bacterial DNA may become encased in the viral capsid instead of the viral genome. When this bacteriophage infects another bacterium, it injects the DNA fragment from the previously infected bacterium. This DNA fragment then becomes inserted into the DNA of the new bacterium. This type of transduction is called generalized transduction.

Check your progress - 4
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.

7. Explain the bacterial structure?
8. What is the function of bacteriophage?
9. What is bacterial recombination?

4.7 1LET US SUM UP

In this unit, we looked at the concept of Viruses and Bacteriophages in Microbiology.
Then we studied about some of the important Discovery of Bacteriophages, their structure, mode of reproduction and diseases spread by them. We also discussed about favorable and unfavorable conditions that affect the growth of these Viruses and Bacteriophages.
The last part of the unit focused on Morphology and its its importance of Viruses and Bacteriophages.

4.8 UNIT- END- EXERCISES

1. What are foodborne viruses?

2. How do viruses contaminate food?
3. Can viruses cause food spoilage?
4. What are the 3 main types of bacteria found in food?
5. What are bacteriophages called?
6. How do bacteriophages replicate?
7. Is bacteriophage harmful to humans?
8. What is the function of a bacteriophage?
9. How many phages are there?
10. What does the collar of a bacteriophage do?
11. Can phages kill viruses?
12. What are the symptoms of bacteriophage?
13. Are bacteriophages alive?
14. How does bacteriophage reproduce?
15. What is bacteriophage and its structure?
16. What is the function of sheath in bacteriophage?

4.9 ANSWER TO CHECK YOUR PROGRESS

1. Viruses are the smallest obligate intracellular parasites that require living host cells in order to multiply and being alive.
2. A universal taxonomic classification of viruses is carried out by the International Committee on Taxonomy of Viruses (ICTV). According to ICTV, the classification is as follows:
    a. Order – virales
    b. Family – viridae
    c. Subfamily – virinae
    d. Genus – virus
    e. Species – virus
3. The replication cycle of viruses
    a. Attachment
    b. Penetration or Viral Entry
    c. Synthesis
    d. Assembly
    e. Release
4. Bacteriophages, also known as phages, are viruses that infect and replicate only in bacterial cells
5. Bacteriophages on the basis of their life cycle
    a. Lysogenic or temperate phages
    b. Lytic phages
6. Bacterial Cell Structure
    a. Cell Wall
    b. Cytoplasm
    c. Cell Membrane or Plasma Membrane
    d. Flagella
    e. Ribosomes
    f. Plasmids
    g. Nucleoid Region

4.10 SUGGESTED READINGS

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BLOCK-II: CONTAMINATION, SPOILAGE, PRESERVATION AND MICROBES OF FRUITS, VEGETABLES AND CEREALS

UNIT- V CONTAMINATION OF FOODS

5.1 Introduction
5.2 Objectives
5.3 Food Contamination and Spoilage
5.3.1 Definition
5.3.2 Sources of Contamination
5.3.3 Types of contamination
5.4 Principles underlying Food Spoilage
5.4.1 Chemical Changes by Microorganisms
5.5 Answers to Check Your Progress Questions
5.6 Summary
5.7Key Words
5.5 Self-Assessment Questions and Answers
5.9Further Readings

5.1. INTRODUCTION

From Block- I, we have gained insight on the types of microbes, functions and the beneficial effects of microorganisms. It is equally imperative to have knowledge and understanding on the adverse effects of microbes on food. Hence, in this unit we shall study about the food contamination and spoilage caused by microorganisms.

5.2. OBJECTIVES

After learning this unit you will be able to:

- Define food contamination.
- Discuss the sources, types and changes caused due to food contamination.
- Explain food spoilage and factors causing it.

5.3. FOOD CONTAMINATION

Food contamination is a serious issue because it results in food borne diseases that each year affect an estimated seventy-six million people in the United States, while leading to some 325,000 hospitalizations and 5,000 deaths. Hence, awareness of potential sources of food contamination is an important component of good nutrition.

5.3.1 Definition

Food Contamination: Food contamination refers to foods that are spoiled or tainted because they either contain microorganisms, such as bacteria or parasites, or toxic substances that make them unfit for consumption.

Food Spoilage: Food spoilage is a metabolic process that causes foods to be undesirable or unacceptable for human consumption due to changes in sensory characteristics. Spoiled foods may be safe to eat, i.e. they may not cause illness because there are no pathogens or a toxin present, but changes in texture, smell, taste, or appearance cause them to be rejected.

5.3.2 Sources of Food Contamination

Food contamination can be microbial or environmental, with the former being more common. Environmental contaminants that can enter the food supply chain include pesticides, heavy metals, and other chemical agents. Many opportunities exist for food to become contaminated as it is produced and distributed. To start with, bacteria are present in the animals raised for food. Meat and poultry can become contaminated during slaughter through cross-contamination from intestinal faecal matter. Similarly, fresh fruits and vegetables can be contaminated if they are washed using water contaminated with animal manure or human sewage. During food processing, contamination is also possible from infected food handlers. Lastly, poor hygiene in the home is also a factor.

Thus, the contamination of food from external sources includes:

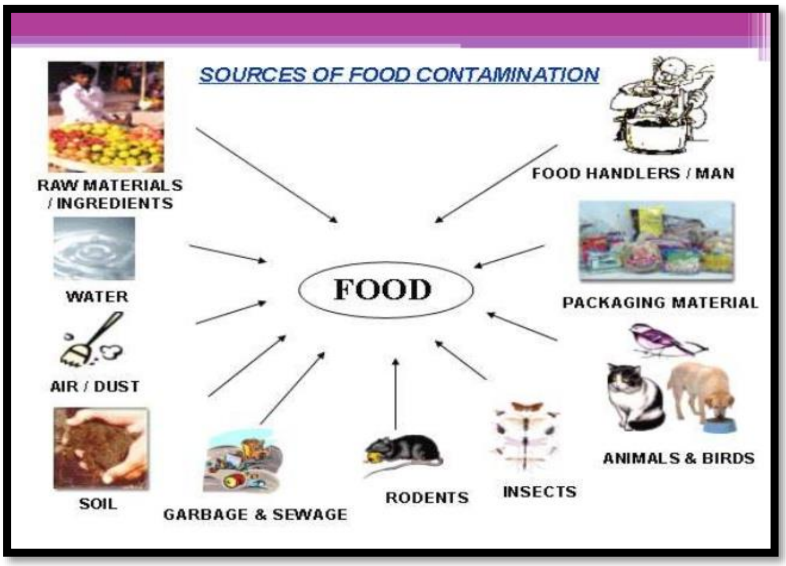


Figure 5.1: Sources of Food Contamination

Micro-organisms: Microorganisms are one of the main source of food contamination. They promote their growth and deteriote the food

Enzymes: The naturally present enzymes in the food changes to toxic when there is change in the pH, temperature etc and makes the food contaminated.

Air: Oxidation, a chemical process that produces undesirable changes in color, flavor and nutrient content results when air reacts with food components. Oxidation is also responsible for rancidity of fats, which is discussed later in this unit. Anti-oxidants leads to discoloration of foods.

Light: Light exposure could result in color and vitamin loss. Light also may be responsible for fat oxidation.

Insects, rodents, parasites and other creatures: These creatures require food to survive and damage food, making it more vulnerable to further deterioration.
Physical damage: Improperly packed foods provide place for microorganisms, air, light and creatures to enter causing food contamination.
Temperature: Microorganisms both spoilage and pathogenic grow rapidly at room temperature. To slow microbial growth, the enzymatic and oxidation processes, store foods at lower temperature

Check Your Progress
1. **Define Food Contamination.**
2. **Define Food spoilage.**

5.2.3 Types of Food Contamination

There are a number of reasons that can lead to food contamination. However, food contamination falls under four different categories which are:

- Biological contamination
- Physical contamination
- Chemical contamination
- Cross-contamination

Let us discuss each in detail:

- **Biological Contamination**

Biological contamination is one of the common causes of food poisoning as well as spoilage. Contamination of food items by other living organisms is known as biological food contamination. During biological contamination, the harmful bacteria spread on foods that you consume. Even a single bacterium can multiply very quickly when they find ideal growth conditions. Not just bacteria, but also their process of multiplying can be quite harmful to humans. The common places where you can find bacteria are dust, raw meat, air, human body, pets and pests, clothes of food handler, kitchen clothes. The best way to avoid food contamination is by washing the food items.
Bacteria and parasites being, the most common causes we shall discuss them here.

Bacterial Food Contamination

Many bacteria can contaminate food. The most common include the following:

- *Campylobacter jejuni*. Mishandling of raw poultry and consumption of undercooked poultry are the main causes of *C. jejuni* contamination

- Clostridium botulinum Bacteria producing a toxin in food responsible for botulism, the deadly paralytic nerve illness
- Escherichia coli. A leading cause of food contamination. Based on a 1999 estimate, 73,000 cases of infection and 61 deaths occur in the United States each year. The E. Coli 0157:H7 strain is found in ground beef, raw milk, chicken, vegetables, and fruit.
- Salmonella typhimurium Salmonella contamination. can occur in meats, poultry, eggs or milk products
- Shigella, The most common food that these bacteria can contaminate include: salads (potato, chicken, sea food, vegetable), raw vegetables, milk and other dairy products, and meat products especially poultry.
- Staphylococcus aureus. Can be found in custard or cream-filled baked goods, ham, poultry, eggs, potato salad, cream sauces, sandwich fillings.
- Vibrio cholera. These bacteria cause the well-known disease cholera that has caused many outbreaks all over the world. It can be transmitted by water or food.
- Vibrio vulnificus. Free-living ocean bacteria that can cause food borne illnesses from contaminated seafood. Especially dangerous in the warm weather months when eating shellfish that are undercooked or raw.
- Spoiled milk is also mostly caused by bacteria such as Lactococcus cremoris or Enterobacter aero-genes that cause the milk to form long white strands.
- Water contamination is usually due to the presence of three bacteria, E. coli, Clostridium perfringens, and enterococci, the bacteria normally found in the feces of people and many animals.

Parasitic Food Contamination

Parasites are organisms that live in or on a host, and obtain nourishment without benefiting or killing the host. They enter the body through the mouth when contaminated food or drink is swallowed. There are many different types and range in size from single-celled, microscopic organisms (protozoa) to larger, multi-cellular worms (helminths) that can be seen without a microscope.

Parasites that contaminate food include:

- Entamoeba histolytica: Parasite that causes amoebic dysentery, characterized by severe diarrhea. It is transmitted by contaminated water, and is often called “traveler’s dysentery” because of its prevalence in developing nations.
- Giardia duodenalis: Microscopic parasite that can live in the intestines of animals and people. It is found in every region of the world and is one of the most common causes of waterborne and foodborne) illness

- Cryptosporidium parvum: Microscopic parasite, a significant cause of water contamination worldwide. It is found in the intestines of many herd animals including cows, sheep, goats, deer, and elk.
- Cyclospora cayetanensis: Single-celled, microscopic parasite. Little is known about this organism, although cases of infection are being reported from various countries with increasing frequency.
- Toxoplasma gondii: Single-celled, microscopic parasite found throughout the world. Found in foods such as raw or undercooked meats, especially pork, lamb, or wild game, and in drinking untreated water.
- Trichinella spiralis: Intestinal roundworm whose larvae may migrate from the digestive tract and form cysts in various muscles of the body. In the United States, infections are most prevalent where pork or wild game is consumed raw or undercooked.
- Taenia saginatajsolium: Taenia saginata (beef tapeworm) and Taenia solium (pork tapeworm) are parasitic worms (helminths). They are now uncommon in the United States, although travelers and immigrants are occasionally infected.

- **Physical Contamination**



Figure 5.2 Physical Contamination of Food

- When harmful objects contaminate the food it leads to physical contamination.
- At times, food items can have both physical and biological contamination.
- Physical contaminants such as rats, hair, pests, glass or metals which can contaminate food and make it unhealthy.
- Some of the safety tips that you can follow when handling food items to prevent food contamination are:
  - Hair-Tie your hair when handling food.
  - Glass or Metal-Clean away cracked or broken crockery and utensils to avoid contamination.
  - Fingernails-Keep your fingernails short or wear clean gloves when handling food
  - Dirt-Wash fruits and vegetables with Vegetable and Fruit Cleaner to remove dirt.
  - Jewelry-Wear minimum jewelry when preparing food.

- **Chemical Contamination**

- Chemical contaminants are one of the serious sources of food contamination.
- These contaminants can also lead to food poisoning.
- Pesticides present in fruits and vegetables are one of the main sources of contamination.
- In addition, kitchen cleaning agents, food containers made of non-safe plastic, pest control products also lead to food contamination.
- Though we make it a point to wash fruits and vegetables thoroughly, however, plain water can't remove all the contaminants.
- The smart kitchen appliance uses ozone disinfection technology that removes contaminants from the surface of the fruits and vegetables to make it safe for consumption.



Figure 5.3: Chemical Contamination of Food

- **Cross-Contamination**
Many of us are not aware of cross contamination; however, this type of contamination can lead to a number of health problems. Cross-contamination takes place when pathogens are transported from any object that you use in the kitchen. Dirty kitchen clothes, unclean utensils, pests, raw food storage can lead to cross-contamination. Here are some of the ways to avoid cross-contamination:
- Personal Hygiene: Thoroughly wash your hands and face when handling food. Coughing, sneezing or even touching your hair can lead to cross contamination.
- Utensils: Use separate utensils to prepare different types of foods. Avoid using the same chopping board and knife for ready to eat foods.
- Storing Food: Make sure raw foods don't come in contact with ready to eat foods. Cover and store raw foods below cooked foods to prevent cross-contamination.
- Disposing Waste: Make sure you store and seal garbage correctly to prevent cross-contamination. Clean and sanitize the waste bins to prevent infestation risk.

Check Your Progress

3. List the types of Contamination.
4. What is Cross contamination?

5.3 Principles Underlying Food Spoilage

India is the second major producer of fruits and vegetables and ranks next to Brazil and China respectively, in the world. It contributes 10 percent of

World fruit production and 14 per cent of world vegetable production. Fruits and vegetables are more prone to spoilage than cereals due to their nature and composition, and this spoilage occurs at the time of harvesting, handling transportation, storage, marketing and processing resulting in waste. Like any other food, fruits and vegetables are also prone to microbial spoilage caused by fungi, bacteria, yeast and moulds. A significant portion of losses of fruits and vegetables during post-harvest period is attributed to diseases caused by fungi and bacteria. The succulent nature of fruits and vegetables makes them easily invaded by these organisms. Besides attacking fresh fruits and vegetables, these organisms also cause damage to canned and processed products. The principles or factors underlying food spoilage are presented in the figure 5.3. The

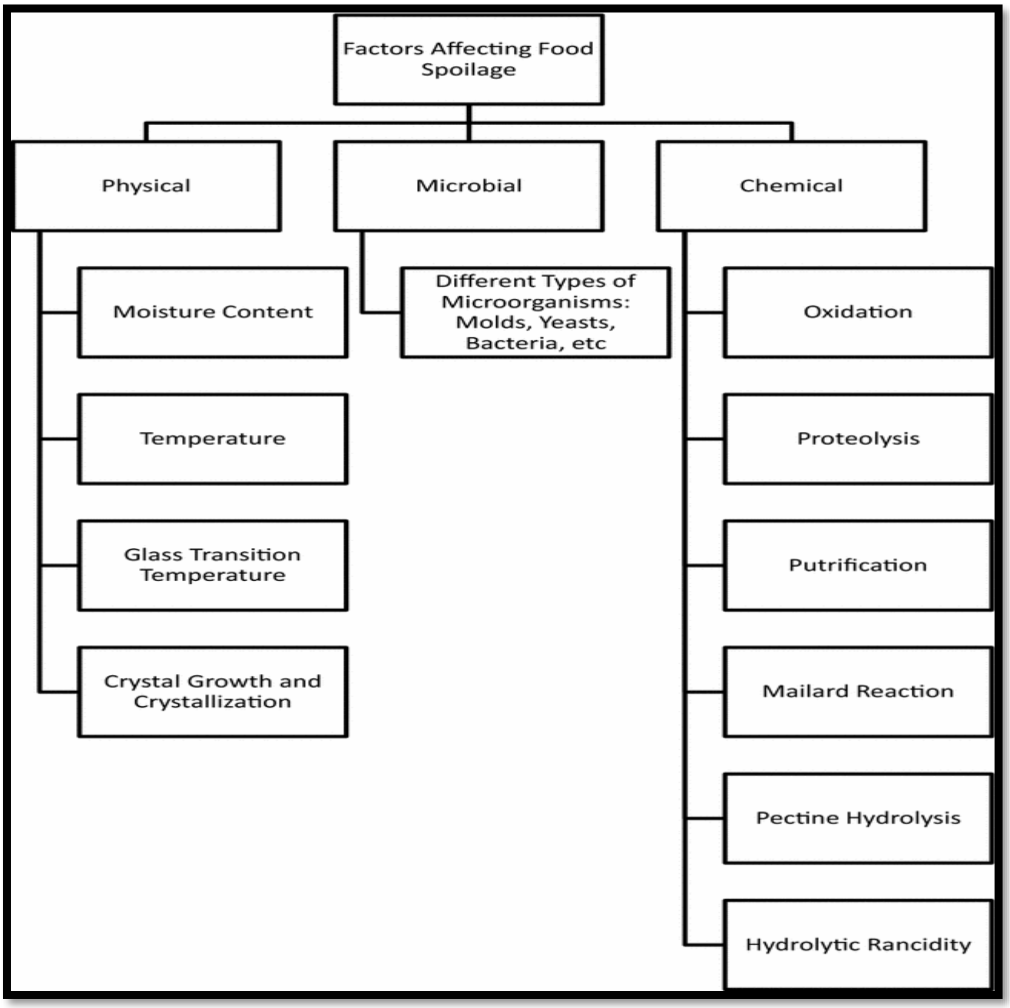


Figure 5.4: Factors Causing Food Spoilage

5.3.1 Chemical Changes by Microorganisms:

Food contamination affects the characteristic texture, colour and produces off-odour in foods like,

- Texture – such as the thinning of sauces from starch degradation.
- Color – including discoloration of meat, fruit or vegetables.
- Off-odour and Off-flavor, which may be due to the breakdown of proteins in meat, taint from packaging, environment or processing, rancidity from lipid oxidation or hydrolysis.

The chemical changes that accompany food contamination are:

OXIDATION: Oxidation, a chemical process that produces undesirable changes in color, flavor and nutrient content, results when air reacts with food components. When fats in foods become rancid, oxidation is responsible. Commonly bacteria takes place in oxidation. To prevent oxidative spoilage,

- Treat the fruit or vegetable with ascorbic acid immediately after cutting into it to stop oxidation. Ascorbic acid is a natural property in many citrus fruits, such as oranges and lemons. Squeeze a few drops of lemon juice on the cut portions of fruit or vegetable.
- Cover the fruit or vegetable tightly with plastic food wrap. Covering the fruit or vegetable will prevent oxygen from reaching the cut cells, and thus prevent oxidation.
- Cook, boil or otherwise heat the fruits and vegetables right after cutting them to prevent oxidation. When fruits and vegetables are cooked, the heat destroys the enzymes that cause oxidation and the resulting discoloration.

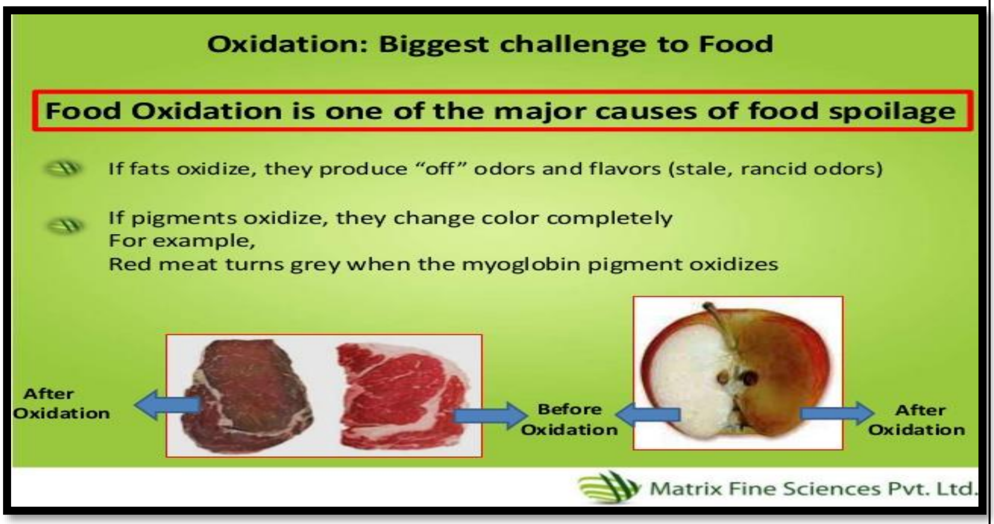


Figure 5.5 Oxidation Process in Foods

MAILLARD REACTION: This reaction takes place between reducing sugars (simple monosaccharides capable of carrying out reduction

reactions) and the amino group of proteins or amino acids present in foods. The products of the Maillard reaction lead to a darkening of colour, reduced solubility of proteins, development of bitter flavours, and reduced nutritional availability of certain amino acids such as lysine. The rate of this reaction is influenced by the water activity, temperature, and pH of the food product. Non enzymatic browning causes spoilage during the storage of dry milk, dry whole eggs, and breakfast cereals. Figure 5.4 clearly depicts the maillard reaction in milk.

DEGRADATION OF N-COMPOUNDS: Foods rich in proteins are degraded by proteolytic microorganisms. Proteins are degraded into its various components due to the action of especially gram-negative, spore forming bacteria, e.g., Proteus, Pseudomonas, some cocci, etc.

DEGRADATION OF CARBOHYDRATES: Foods rich in carbohydrates are degraded by carbohydrate fermenting microorganisms, particularly yeasts and moulds. Bacteria like Micrococcus, Leuconostoc, and Streptococcus can also degrade carbohydrates.
Carbohydrate foods + Carbohydrate fermenting microorganisms→ Acids + Alcohols + Gases.

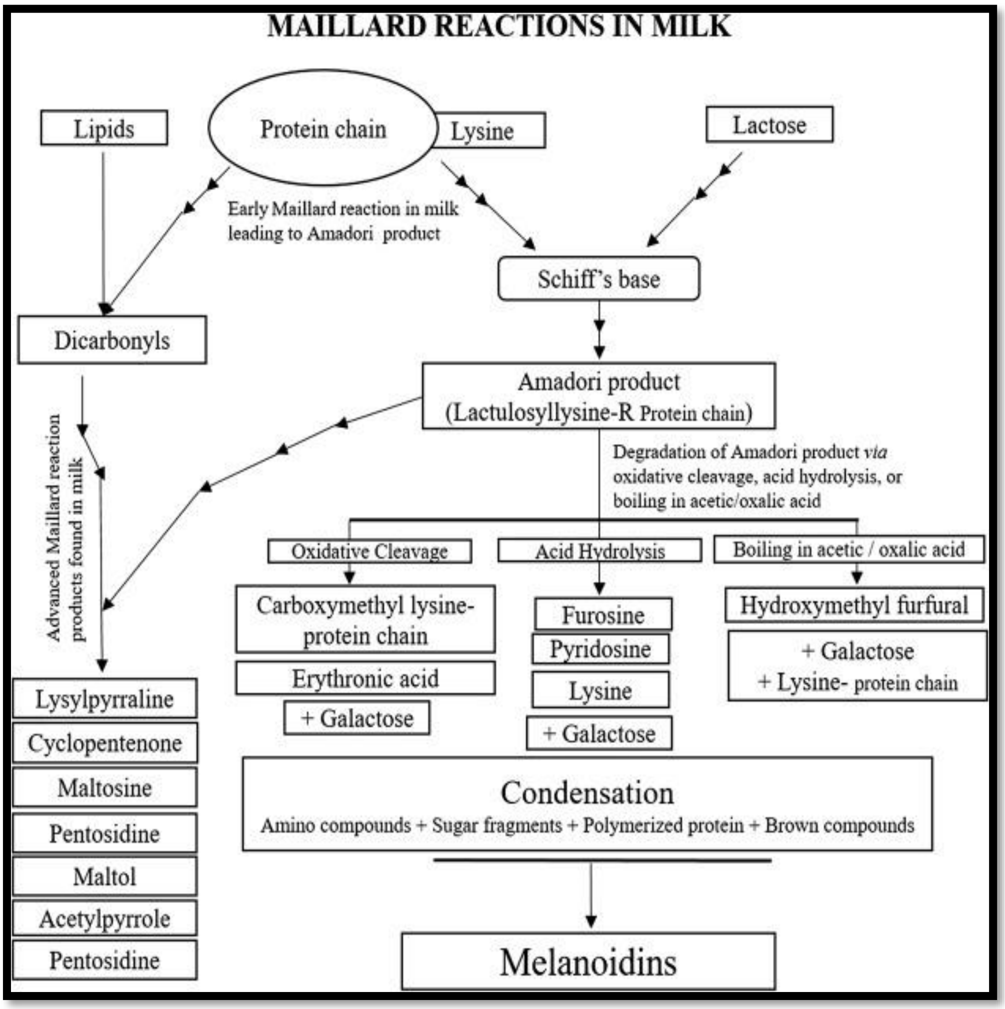


Figure 5.6 Maillard Reaction

DEGRADATION OF LIPIDS: Foods rich in fats are attacked by relatively few microorganisms such as moulds and some gram- negative bacteria. These microorganisms are, therefore, lipolytic in nature.
Fatty foods + Lipolytic microorganisms→ Fatty acids + Glycerol

PROTEOLYSIS: The breakdown of proteins or peptides into amino acids by the action of enzymes. Proteolysis cells contain proteolytic enzymes which hydrolyse proteins into amino acids, which is responsible for the ageing and spoilage of foods. Proteolysis is favoured by:

- Storage at lower temperature
- By the destruction of lactis and other acid formers by heat
- By the destruction of formed acid in milk by molds and yeasts
- The neutralization of acids by product of other organisms

Example: Proteolysis in meat: suitable action of proteolytic enzymes on meat produces tendering effect which improve meat quality. Undesirable action of this enzyme causes spoilage of meat. This is illustrated in figure 5.5.

Proteolysis in milk: The hydrolysis of milk proteins by microorganisms usually is accompanied by the production of bitter flavor caused by some of the peptides released.
Protein foods + Proteolyticmicrobes→ Amino acids + Amines + Ammonia + Hydrogen sulfide

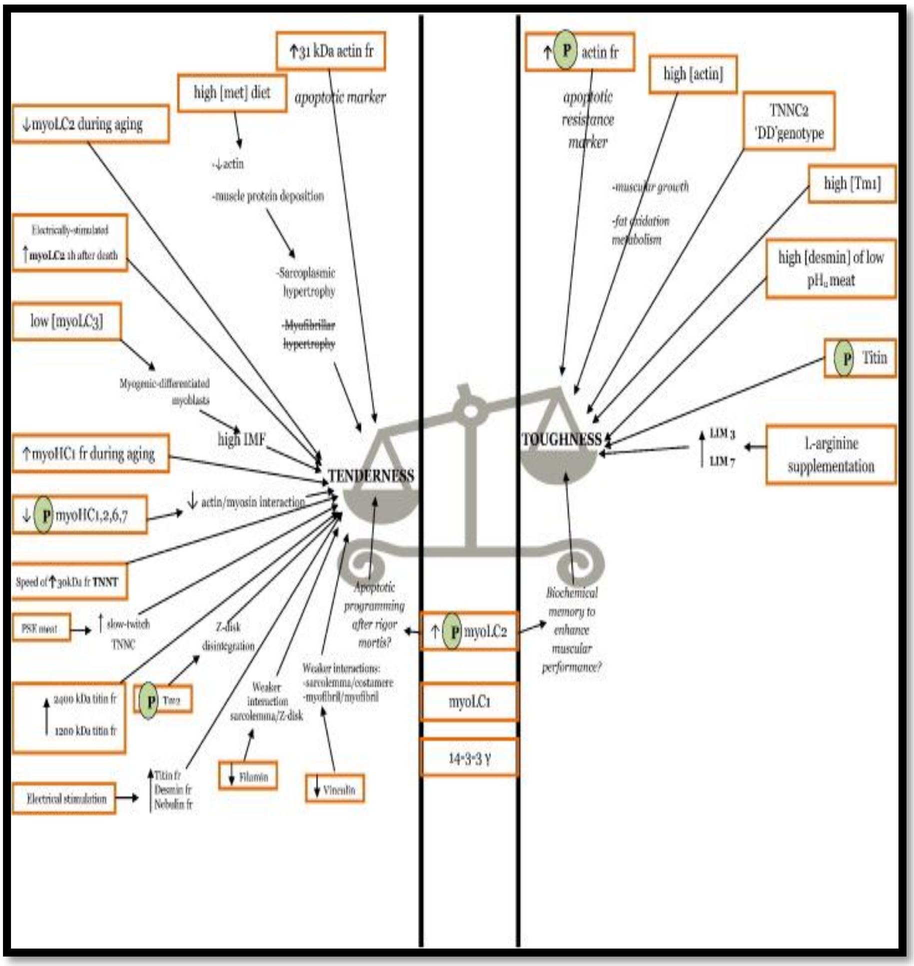


Figure 5.7 Proteolysis

RANCIDITY: The unpleasant odour and flavour in food, as a result of deterioration of fat or oil in food is known as Rancidity. Rancidity may be due to hydrolysis, oxidation or microbes.

Measures to Overcome Rancidity:

1. The first way to prevent rancidity is to eliminate oxygen. Think of vacuum packaging a product.
2. Prevent using unsaturated fatty acids, saturated ones won't oxidize.
3. Prevent the formation of those first radicals. Since light (especially UV light) can initiate this formation it would be wise to eliminate that (think of aluminium cans in which olive oil is packaged).
4. 'Catch' anti-oxidants as soon as they are formed. This can be done by adding anti-oxidants for instance.
5. Since metals can also induce radical formation another method is to 'catch' or prevent the presence of these metals.

5.4 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. Food Contamination: Food contamination refers to foods that are spoiled or tainted because they either contain microorganisms, such as bacteria or parasites, or toxic substances that make them unfit for consumption.

2. Food Spoilage**:** Food spoilage is a metabolic process that causes foods to be undesirable or unacceptable for human consumption due to changes in sensory characteristics. Spoiled foods may be safe to eat, i.e. they may not cause illness because there are no pathogens or a toxin present, but changes in texture, smell, taste, or appearance cause them to be rejected.
3. Food contamination falls under four different categories which are:
   Biological contamination, Physical contamination, Chemical contamination and Cross-contamination
4. Cross-contamination takes place when pathogens are transported from any object that you use in the kitchen. Dirty kitchen clothes, unclean utensils, pests, raw food storage can lead to cross-contamination. Here are some of the ways to avoid cross-contamination:
   - Personal Hygiene: Thoroughly wash your hands and face when handling food. Coughing, sneezing or even touching your hair can lead to cross contamination.
   - Utensils: Use separate utensils to prepare different types of foods. Avoid using the same chopping board and knife for ready to eat foods.
   - Storing Food: Make sure raw foods don't come in contact with ready to eat foods. Cover and store raw foods below cooked foods to prevent cross-contamination.
   - Disposing Waste: Make sure you store and seal garbage correctly to prevent cross-contamination. Clean and sanitize the waste bins to prevent infestation risk.

5.5 SUMMARY

- Food Contamination and spoilage not only leads to food waste but also pose deleterious effects on human health. Harmful bacteria are called pathogenic bacteria because they cause disease and illnesses like strep throat, staph infections, cholera, tuberculosis, and food poisoning.
- Common cases of food poisoning will typically include at least three of the following symptoms like abdominal cramps, diarrhoea, vomiting, loss of appetite, mild fever, weakness or nausea.
- Transmission usually occurs via the fecal/oral route with the ingestion of the pathogen present in the contaminated food.
- After they are ingested, there is a delay, (incubation period) before symptoms appear, that may range from hours to days, depending on the organism.
- During this period, the microbes pass through the stomach into the intestine, where they start to multiply.

- Some types stay in the intestine, others produce a toxin that is absorbed into the bloodstream, and others can directly invade the deeper body tissues.
- The salmonella in eggs, E-coli bacteria in ground beef, and pesticides in infant formula are just a few contaminations since the turn of the century that have ravaged the food supply and crippled the food processing and manufacturing industries.
- Cross contamination is an important area of food safety, along side temperature control as it is one of the most common causes of food poisoning. The most common example of cross contamination is where raw food, which may naturally contain bacteria, contaminates ready to eat food.
- The four steps to fight bacteria: viz: **Clean:** Wash hands and surfaces often. Bacteria can spread throughout the kitchen and get onto cutting boards, utensils, sponges and counter tops. **Separate:** Don't cross-contaminate, **Cook**: Cook to Proper Temperatures, **Chill**: Refrigerate promptly.
- Chemical contaminants can be present in foods mainly as a result of the use of agrochemicals, such as residues of pesticides and veterinary drugs, contamination from environmental sources (water, air or soil pollution), cross-contamination or formation during food processing, migration from food packaging materials.
- Simple precautions can reduce the risk of contamination. For instance, meat left at room temperature promotes bacterial growth and refrigeration helps to suppress it. One can also be careful about eating certain foods. Eating raw meats and fish should be avoided as well as salads prepared in restaurants
- Where meats and vegetables share a common surface during preparation.
- Wash hands, utensils and food surfaces often. Keeping hands, utensils and food preparation surfaces clean can prevent cross-contamination, i.e. the transfer of harmful bacteria from one surface to another.
- Throw out any leftovers that have been at room temperature for more than two hours or in hot weather for more than an hour. If cold food needs to sit out for longer than two hours, use a tray of ice under the food to keep it cold. If hot food must sit out for longer than two hours, use warming trays to keep the food hot

5.6 KEYWORDS

- **Proteolysis:** The breakdown of proteins or peptides into amino acids.
- **Parasites**: Organisms that live in or on a host, and obtain nourishment without benefiting or killing the host.

5.7 SELF ASSESSMENT QUESTIONS AND ANSWERS

Short Answer Questions

1. Define and explain the causes of food contamination.
2. Describe physical contamination of food.
3. What is cross contamination? List the ways to prevent it.

Long Answer Questions

1. Explain in detail the chemical changes caused by microorganisms.
2. Highlight the sources of food contamination.

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UNIT-VI GENERAL PRINCIPLES OF FOOD PRESERVATION

6.1 Introduction
6.2 Objectives
6.3 Principle of food preservation
6.4 Natural preservatives
6.5 chemical preservatives
6.6 Summary
6.7 Key Words
6.8 Self-Assessment Questions and Answers
6.9 Further Readings

6.1. INTRODUCTION

Food preservation is the process of treating and handling food to stop or greatly slow down spoilage (loss of quality, edibility or nutritive value) caused or accelerated by micro-organisms. Preservation usually involves preventing the growth of bacteria, fungi, and other micro-organisms, as well as retarding the oxidation of fats which cause rancidity. It also includes processes to inhibit natural ageing and discoloration that can occur during food preparation such as the enzymatic browning reaction in apples after they are cut. Preservative for food may be defined as any chemical compound and/or process, when applied to food, retard alterations caused by the growth of microorganisms or enable the physical properties, chemical composition and nutritive value to remain unaffected by microbial growth.

6.2. OBJECTIVES

After learning this unit you will be able to:

- Define food preservation
- Discuss the sources, types and changes caused due to food preservation.

6.3. Principles of Food Preservation

The principles of various methods for food preservation are as

1) Prevention or delay of microbial decomposition

• By keeping out microorganisms (asepsis)
• By removal of microorganisms
• By hindering the growth and activity of microorganisms (e.g. by low temperatures, drying, anaerobic conditions, or chemicals)
• By killing the microorganisms (e.g. by heat or radiation)

2) Prevention or delay of self-decomposition of the food

• By destruction or inactivation of food enzymes (by blanching)
• By prevention or delay of chemical reactions (By using antioxidant)

6.4 Methods of Food Preservation

Preservation of food is achieved by application of physical, chemical and/or biological methods are as follows:

Physical methods

• Cooling to
→ Low temperature refrigeration (0 to 7°C) - preserves for shorter period (days) → Freezing - preserves for several months
• Heating → pasteurization, cooking, sterilization etc
• Exposure to ionizing radiation → U.V., γ, etc
• Application of high pressure
• Drying → removal of water to a level which does not support the growth of microorganism

Chemical methods

• Quite often it is either impossible or undesirable to employ conventional physical methods of the preservation.
• In such situation one has to opt for chemical methods of preservation.
• It involves application of chemical additives which act as antimicrobial agents.

Biological methods

Souring (fermentation) lactic and acetic acid, e.g. cheese and cultured milk.

6.4.1 Thermal treatment

The term "thermal" refers to processes involving heat. Heating food is an effective way of preserving it because the great majority of harmful pathogens are killed at temperatures close to the boiling point of water. In this respect, heating foods is a form of food preservation comparable to that of freezing but much superior to it in its effectiveness. A preliminary step in many other forms of food preservation, especially forms that make use of packaging, is to heat the foods to temperatures sufficiently high to destroy pathogens.

In many cases, foods are actually cooked prior to their being packaged and stored. In other cases, cooking is neither appropriate nor necessary. The most familiar example of the latter situation is pasteurization. Conventional methods of pasteurization called for the heating of milk to a temperature between 145 and 149 °F (63 and 65 °C) for a period of about 30 minutes, and then cooling it to room temperature. In a more recent revision of that process, milk can also be "flash-pasteurized" by raising its temperature to about 160 °F (71 °C) for a minimum of 15 seconds, with equally successful results. A process known as ultra-high pasteurization uses even higher temperatures of the order of 194 to 266 °F (90 to 130°C) for periods of a second or more.

6.4.2 Low temperature

The lower the temperature, the slower will be chemical reactions, enzyme action, and microbial growth. Each microorganism present has an optimal temperature for growth and a minimal temperature below which it cannot multiply. As the temperature drops from this optimal temperature toward the minimal, the rate of growth of the organism decreases and is slowest at the minimal temperature. Cooler temperatures will prevent growth, but slow metabolic activity may continue. Most bacteria, yeasts, and molds grow best in the temperature range 16-38^{o}C (except psychrotrophs). At temperatures below 10^{o}C, growth is slow and becomes slower the colder it gets. The slowing of microbial activity with decreased temperatures is the principal behind refrigeration and freezing preservation.

6.4.3 Drying

One of the oldest methods of food preservation is by drying, which reduces water activity sufficiently to prevent or delay microbial growth. The term water activity is related to relative humidity. Relative humidity refers to the atmosphere surrounding a material or solution. Water activity is the ratio of vapour pressure of the solution to the vapour pressure of pure water at the same temperature. Under equilibrium conditions water activity equals RH/100. At the usual temperatures permitting microbial growth, most bacteria require a water activity as low as 0.90-1.00. Some yeasts and molds grow slowly at a water activity as low as 0.65. Food is dried either partially or completely to preserve it against microbial spoilage.

6.4.4 Irradiation

The lethal effects of radiation on pathogens has been known for many years. The radiation used for food preservation is normally gamma radiation from radioactive isotopes or machine-generated x rays or electron beams. One of the first applications of radiation for food preservation was in the treatment of various kinds of herbs and spices, an application approved by the United States Food and Drug Administration (FDA) in 1983. In 1985, the FDA extended its approval to the use of radiation for the treatment of pork as a means of destroying the pathogens that cause trichinosis. Experts predict that the ease and efficiency of food preservation by means of radiation will develop considerably in the future.

6.5 Preservation of Food through Irradiation

Radiation processing of food involves exposure of food to short wave radiation energy to achieve a specific purpose such as extension of shelf-life, insect disinfestation and elimination of food borne pathogens and parasites. In comparison with heat or chemical treatment, irradiation is considered a more effective and appropriate technology to destroy food borne pathogens. It offers a number of advantages to producers, processors, retailers and consumers. Radiation processing of food involves exposure of food to short wave radiation energy to achieve a specific purpose such as

Extension of shelf-life, insect disinfestation and elimination of food borne pathogens and parasites.

6.5.1 Type of Radiation

The type of radiation used in processing materials is limited to radiations from high energy gamma rays, X-rays and accelerated electrons. These radiations are also referred to as ionizing radiations because their energy is high enough to dislodge electrons from atoms and molecules and to convert them to electrically-charged particles called ions.

Gamma rays and X-rays, like radio waves, microwaves, ultraviolet and visible light rays, form part of the electromagnetic spectrum and occur in the short-wavelength, high-energy region of the spectrum and have the greatest penetrating power. They have the same properties and effects on materials, their origin being the main difference between them. X-rays with varying energies are generated by machines. Gamma rays with specific energies come from the spontaneous disintegration of radionuclides.

Naturally occurring and man-made radionuclides, also called radioactive isotopes or radioisotopes, emit radiation as they spontaneously revert to a stable state. The time taken by a radionuclide to decay to half the level of radioactivity originally present is known as its half-life, and is specific for each radionuclide of a particular element. Only certain radiation sources can be used in food irradiation. These are the radionuclides cobalt-60 or cesium-137; X-ray machines having a maximum energy of five million electron volts (MeV) (an electron volt is the amount of energy gained by an electron when it is accelerated by a potential of one volt in a vacuum); or electron accelerators having a maximum energy of 10 MeV. Energies from these radiation sources are too low to induce radioactivity in any material, including food.

6.5.2 Unit of Radiation Dose

Radiation dose is the quantity of radiation energy absorbed by the food as it passes through the radiation field during processing. It is measured using a unit called the Gray (Gy).

In early work the unit was the rad (1 Gy = 100 rads; 1 kGy =1000 Gy).

6.5.3 Application of Radiation processing of food

Interest in the practical application of the process is emerging for many reasons. High food losses caused by insect infestation, microbial contamination and spoilage; mounting concern over food borne diseases, harmful residues of chemical fumigants and the impact of these chemicals on the environment, the stiff standards of quality and quarantine restrictions in international trade are some of the reasons. Though irradiation alone cannot solve all the problems of food preservation, it can play an important role in reducing post-harvest losses and use of chemical fumigants.

Preservative for food may be defined as any chemical compound and/or process, when applied to food, retard alterations caused by the growth of microorganisms or enable the physical properties, chemical composition and nutritive value to remain unaffected by microbial growth. Some

chemicals have been used traditionally since several decades as direct or indirect inhibitors of microbial growth and are still widely used despite theirlimitations. The majority of food preservation operations used today also employ some kind of chemical additive to reduce spoilage. Of the many dozens of chemical additives available, all are designed either to kill or retard the growth of pathogens or to prevent or retard chemical reactions that result in the oxidation of foods.

Some familiar examples of the former class of food additives are sodium benzoate and benzoic acid; calcium, sodium propionate, and propionic acid; calcium, potassium, sodium sorbate, and sorbic acid; and sodium and potassium sulfite. Examples of the latter class of additives include calcium, sodium ascorbate, and ascorbic acid (vitamin C); butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT); lecithin; and sodium and potassium sulfite and sulphur dioxide.

Classification of Preservatives

According to FSSA rules → class I and class II preservatives

Class I preservatives

a. Common salt
b. Sugar
c. Dextrose
d. Glucose
e. Spices
f. Vinegar or acetic acid
g. Honey
h. Edible vegetable oil

Addition of class I preservatives in any food is not restricted, unless otherwise provide in the rule.

Class II preservatives

a. Benzoic acid including salts their of
b. Sulphurous acid including salts theirof
c. [Nitrates of] nitrites of sodium or potassium
d. Sorbic acid including its sodium, potassium and calcium salts
e. Nicin
f. Propionic acid including salts theirof
g. Methyl or propyl para-hydroxy benzoate
h. Sodium diacetate
i. Sodium, potassium and calcium salts of lactic acid

Use of class II preservatives is restricted. They shall be added to only specified product and at a concentration not exceeding the proportion specified for the product

Use of more than one class II preservative is prohibited. No person shall use in or upon a food more than one class II preservative

Benzoic acid and its salt

This is widely used as an antimicrobial agent. Benzoate is more effective against yeasts and bacteria than molds. Antimicrobial activity is achieved by inhibition in enzymatic system of microbial cells, affecting acetic acid metabolism, citric acid cycle and oxidative phosphorylation.

Antimicrobial activity is affected by pH of medium. The maximum inhibition occurs at pH value of 2.5 to 4.0 and it decreases when pH rises above 4.5.

The food products preserved with the benzoate include fruit juices and drinks, salads, jams and jellies, pickles, dried fruits and preserves, ketch up and sauce, syrup, carbonated beverages, bakery items, salad dressings, margarine and other fat spreads, spices.

Sulphur dioxide and sulfites

Sulphur dioxide (SO2) gas is one of the oldest antimicrobial agents. It is a colourless, nonflammable gaseous compound or liquid under pressure with a suffocating pungent odour. When dissolved in water of foods, it yields sulphurous acid and its ions, owing to its solubility in water.

Sulphite salts such as sodium sulphite, sodium bisulphite, potassium sulphite, potassium bisulphite, sodium metabisulphite, potassium metabisulphite used as preservatives. When dissolved in water, form sulphurous acid, bisulphite and ions. Sulphurous acid formed from these compounds is an active antimicrobial substance. The effectiveness of sulphurous acid is enhanced at low pH values. Antimicrobial activity of sulfites against yeasts, molds and bacteria is selective, with certain species being more sensitive to inhibition them others. Bacteria are generally more sensitive to inhibition than yeasts and molds. In addition to antimicrobial action, they are also used, to prevent enzymatic and non enzymatic changes as well as discoloration in some foods. Sulphur dioxide and sulphites are used in fruit products such as fruit juice concentrate, squashes, pickles and chutneys.

Sorbic acid and its salts

Sorbic acid and its salts (calcium, potassium or sodium salts) are effective antimicrobial agents against yeast and molds, as well as bacteria. They are less effective against bacteria. Sorbate has an upper pH limit for activity around 6.0-6.5. The food products preserved with sorbates are carbonated beverages, salad dressings, tomato products, jams, jellies, syrup, candy and chocolate syrup, cheese, sausages, smoked fish, fruit juices, grains, breads and cakes.

Propionic acid and its salts

Propionic acid & its salts (Ca & Na) are used most extensively in the prevention of mold growth and rope development in baked goods and for mold inhibition in many cheese foods and spreads. They are more effective against molds as compared to yeasts and bacteria. Propionates has an upper pH limit for activity around 5 to 6.

Lactic acid and its salts

Lactic acid is formed during fermentation of lactose by lactic acid bacteria. Lactic acid & its salts are not very common & not easily available. It can be used in pickles (with acetic acid), fermented dough crispy biscuits, some beverages, dairy products & meat & meat products. Calcium lactate is used as a firming agent in pickles, fruits & vegetables. Na & K lactate are also recommended with sodium diacetate for control of food poisoning & other bacteria in meat product.

Acetic acid

Acetic acid has antimicrobial properties. The action tends to be static rather than cidal. It is more effective against bacteria & yeast then molds. A 5 to 10 % solution of acetic acid is known as Vinegar. Acetic acid in the form of vinegar is used in mayonnaise, pickles, sauce, pickled sausage etc.

Sodium chloride (common salt)
Antimicrobial action of NaCl arises from its lowering water activity (aw) of the food product. This reduces available water in food to the extent which renders condition unfavorable for microbial growth. At higher concentration it has a pronounced bacteriostatic action. The 10% NaCl inhibits the growth of most bacteria. Delaying action upon microorganisms- Creates dehydration of microbial cell—by osmosis—altering results into plasmosis of the cell. Reduction in solubility of oxygen in water decreases oxygen level in food—reduce growth of aerobic microorganisms. It is more effective against bacteria & mold compare to yeast. One of the traditional method of food preservation. Mainly used to preserve pickles, meat & fish. Fish is usually salted by immersing in brine or by mixing with dry salt. High important as a preservative for cheese & table butter. Depending upon type of cheese salt content varied from 1 to 5 %. In table butter salt is added at a max concentration as 3%.

Sucrose (sugar)

More effective against bacteria & mold compared to yeast. Antimicrobial action of sucrose arises from, lowering water activity (aw) of the food product—reduce the available water in food to the extent which renders condition unfavourable for microbial growth. This creates dehydration of microbial cell—by osmosis results into plasmosis of the cells. The food products preserved with sugar are fruit products (jam, jellies, squash etc.), dairy products (sweetened condensed milk, sweets).

6.6 SELF ASSESSMENT QUESTIONS AND ANSWERS

1. What is pasteurization?

2. Describe the preservation of food by canning.
3. Write notes on thawing.
4. What are the factors that occur during freezing?
5. Describe freeze drying.
6. List the factors involved in the control of drying
7. Explain the pretreatment of plant material before the drying process.
8. What are intermediate moisture foods?
9. List the microorganisms in dry milk

6.7 FURTHER READINGS

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UNIT VII – CONTAMINATION, PRESERVATION, AND SPOILAGE OF VEGETABLES AND FRUIT

7.1. Introduction
7.2. Objectives
7.3. Microbiological Spoilage of Fresh Whole Fruits and Vegetables
7.4. Contamination
7.5 Preservation of vegetables
7.6 Preservation of Fruits and Fruit Products
7.7. Spoilage
7.8. Question
7.9. Suggestion for reading

7.1. INTRODUCTION

Consumption of fruit and vegetable products has dramatically increased in the United States by more than 30% during the past few decades. It is also estimated that about 20% of all fruits and vegetables produced is lost each year due to spoilage. The focus of this chapter is to provide a general background on microbiological spoilage of fruit and vegetable products that are organized in three categories: fresh whole fruits and vegetables, fresh-cut fruits and vegetables, and fermented or acidified vegetable products. This chapter will address characteristics of spoilage microorganisms associated with each of these fruit and vegetable categories including spoilage mechanisms, spoilage defects, prevention and control of spoilage, and methods for detecting spoilage microorganisms.

7.2. OBJECTIVES

After going through this unit, you should be able to:

- Discuss about fruits and vegetables preservation
- Contamination and spoilage of fruits and vegetables
- Control micro organism

7.3. Microbiological Spoilage of Fresh Whole Fruits and Vegetables

- During the period 1970–2004, US per capita consumption of fruits and vegetables increased by 19.9%, to 694.3 pounds per capita per year (ERS, 2007). Fresh fruit and vegetable consumption increased by 25.8 and 32.6%, respectively, and far exceeded the increases observed for processed fruit and vegetable products. If US consumption patterns continue in this direction, total per capita consumption of fresh fruits and vegetables would surpass consumption of processed fruits and vegetables within the next decade. This shift toward overall increased produce consumption can be attributed, at least in part, to increased

awareness in healthy eating habits as revealed by a broad field of research addressing food consumption andHealth and promoted by the National Cancer Institute with the 5-A-Day Challenge along with the USDA-revised Food Pyramid. Additional factors influencing greater fresh produce consumption are the increased availability of fresh produce throughout the country throughout the year, increased diversity of selection at the retail level and rapid growth in the fresh-cut, ready-to-eat produce sector. According to a USDA-Economic Research Service study in 1995, 18.9 billion pounds of fresh fruits and vegetables were lost annually due to spoilage, which was 19.6% of all US losses of edible foods that year. The portion of loss specifically due to microbiological spoilage was not reported.

- Most microorganisms that are initially observed on whole fruit or vegetable surfaces are soil inhabitants, members of a very large and diverse community of microbes that collectively are responsible for maintaining a dynamic ecological balance within most agricultural systems. Vectors for disseminating these microbes include soil particles, airborne spores, and irrigation water. Most bacteria and fungi that arrive on the developing crop plant either are completely benign to the crop's health or, in many instances, provide a natural biological barrier to infestation by the subset of microorganisms responsible for crop damage The even smaller subset of bacteria and fungi responsible for causing spoilage to the edible portion of the crop plant is the subject of this section.
- Spoilage microorganisms can be introduced to the crop on the seed itself, during crop growth in the field, during harvesting and postharvest handling, or during storage and distribution. Those same types of soil-borne spoilage microbes that occur on produce are the same spoilage microorganisms that are present on harvesting equipment, on handling equipment in the packinghouse, in the storage facility, and on food contact surfaces throughout the distribution chain. Therefore, early intervention measures during crop development and harvesting through the use of good agricultural practices (GAP) will provide dramatic reductions in yield loss due to spoilage at all subsequent steps in the food-to-fork continuum. Examples of GAPs include foliar fungicide application in the field, cross-contamination prevention measures in the packinghouse and storage facility, and use of postharvest fungicides. These practices also will enhance substantially the food safety and shelf life of fresh-cut produce

In 1998, FDA published the Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables, recommending GAPs that growers, packers, and shippers implement to address the common microbiological hazards that may be associated with their operations (FDA, 1998). These GAPs are organized in eight categories:

I. Water

II. Manure and municipal bio solids

III. Worker health and hygiene

IV. Sanitary facilities

V. Field sanitation

VI. Packing facilities sanitation

VII. Transportation

VIII. Trace back

In addition, FDA worked with the produce industry to develop commodity specific food safety guidelines for sprouts, lettuce and leafy greens, melons, and tomatoes that provided metrics for soil and water amendments as well as adjacent land usage. In March 2007, FDA issued a draft final version of its "guide" (FDA, 2007). These should also improve substantially the food safety and shelf life of fresh-cut produce (see "Microbiological Spoilage of Fresh-Cut Fruits and Vegetables").

7.4 CONTAMINATION

- As soon as fruits and vegetables are gathered into boxes, lugs, baskets, or trucks during harvesting, they are subject to contamination with spoilage organisms from each other and from the containers unless these have been adequately sanitized. During transportation to market or the processing plants, mechanical damage may increase susceptibility to decay and growth of microorganism may take place. Precooling of the product and refrigeration during transportation will slow such growth.
- Washing the fruit or vegetable may involve a preliminary soaking or may be achieved by agitation in water, or preferably, by a spray treatment. Soaking and washing by agitation tend to distribute spoilage organisms from damaged to whole foods. Recirculated or reused water is likely to add organisms, and the washing process may moisten surfaces enough to permit growth of organisms during a holding period. Washing with detergent or germicidal solutions will reduce numbers of microorganisms on the foods.

7.5 PRESERVATION OF VEGETABLES

Microorganisms on the surfaces of freshly harvested fruits and vegetables include not only those of the normal surface flora but also those from soil and water and perhaps plant pathogens. Any of a number of kinds of molds also may be there, and sometimes a few yeasts. If the surfaces are moist or the outer surface has been damaged, growth of some microorganisms may take place between harvesting and processing or consumption of the vegetables. Adequate control of temperature and humidity will reduce such growth.

- **Asepsis**
  While a limited amount of contamination of vegetables will take place between harvesting and processing or consumption, gross contamination can be avoid. Boxes, lugs, baskets, and other containers should be practically free of the growth of microorganisms, and some will need cleaning and sanitation between uses. Examples, are the lugs or other containers used for transporting peas to the processing plant.

Removal OF Microorganism

Thorough washing of vegetables removes most of the casual contaminants on the surface but leaves much of the natural microbial surface flora. Unless the wash water is of good bacteriological quality, it may add organisms, and subsequently growth may take place on the moist surface. For, example, can be removed by washing with a non-ionic detergent solution.

- **Use of heat**
  Vegetables to be dried or frozen, and some to be canned, are scalded or blanched to inactivity their enzymes. At the same time the numbers of microorganisms are reduced appreciably, perhaps by 1,000 – to – 10,000 fold.
- **Use of low temperature**
  As has been indicated, a few kinds of vegetables that are relatively stable, such as root crops, potatoes, cabbage, and celery, can be preserved for a limited time by common or cellar storage.
- **Chilling**
  Most vegetables to be preserved without special processing are cooled promptly and kept at chilling temperature. The chilling is accomplished by use of cold water, ice, or mechanical refrigeration or by vacuum cooling, as used for lettuce. In many cases precooling, i.e., cooling before normal cold storage, is done immediately after harvesting by use of a cold water spray, a practice referred to as hydro cooling.
- **Freezing**

The selection and preparation of vegetables, their blanching, their freezing, on the surface of vegetables are the microorganisms of the natural flora, plus contaminants from soil and water. If the surfaces are moist, growth of some of these organisms will take place before the vegetable reaches the freezing plant.

The kinds of bacteria most likely to grow on thawing will depend on the temperature and the elapsed time. Spices of Micrococcus are predominant on thawing vegetables such as sweet corn and peas when the temperature of thawing is fairly low, although Achromobacter and enterobacter spp. Also are commonly present. Lactobacilli are also common on peas under such conditions. One spices of Micrococcus may grow at first, followed by another species later. At higher temperatures, Species of Flavobacterium also may multiply.

Bacterial counts in frozen vegetables may range from a few to 10^5 per gram. Frequently, coliforms and enterococci can be recovered. The presence of E. coli, however, is unusual and can lead one to question sanitary practices.

- **Drying**

As the methods of drying vegetables and vegetable products have improved, public acceptance has increases, so that now a number of dried food products have wide sale. Dried vegetables and vegetable product are used in dried soups, and dried spices and condiments are used as flavouring materials.

- **Use of preservatives**

The addition of preservatives to vegetables is not common, although the surfaces of some vegetables may receive special treatment. Rutabagas and turnips sometimes are paraffined to lengthen their keeping time. Zinc carbonate has been reported to eliminate most mold growth on lettuce, beets, and spinach. Biphenyl vapors will control Fusarium on potatoes. A controlled atmosphere of carbon dioxide or ozone about chilled vegetables has been tried experimentally but has had little practical use.

Added preservative

Sodium chloride is the only added chemical preservative in common use. The amount added to vegetables may vary from the 2.25 to 2.5 percent in making sauerkraut up to saturation for cauliflower. The lower concentrations of salt permit an acid fermentation by bacteria to take place; as the percentage of salt is increased, the rate of acid production becomes slower until a level of salt is reached that will permit no growth or production of acid.

Developed preservatives

At room temperature an acid fermentation is normal for shredded, chopped, or crushed vegetables

containing sugar, but instead of a clean, acid flavor from the action of lactic acid bacteria, undesirable flavors and changes in body may result from growth of coliform bacteria, bacilli, anaerobes, proteolytic bacteria, and others.

Preservation by irradiation

Experimental treatment with gamma rays to inactivate microorganisms causing decay, followed by storage, has resulted in discoloration, softening, or other deterioration of most vegetables. However, irradiation has been used successfully to delay sprouting of potato, onions, and garlic and to kill insect reproduction on some vegetables.

7.6 PRESERVATION OF FRUITS AND FRUIT PRODUCTS

In general, principles similar to those for both vegetables and vegetable products are involved in the preservation of fruits and fruit products. The surfaces of healthy fruits include the natural flora plus contaminating microorganisms from soil and water and therefore have a surface flora much like that listed for vegetables; however, yeasts and molds will predominate. In addition, some fruits will contain plant pathogens or saprophytic spoilage organisms which may grow subsequent to harvesting. Such defective fruits should be sorted, and spoilad portions may be trimmed out. A few microorganisms are present in the interior of occasional healthy fruits.

- **Asepsis**

  Fruits, like vegetables, may be subject to contamination between harvesting and processing from containers and from spoiling fruits, and care should be taken to avoid such contamination as much as possible. Before harvest, fruits are usually exposed to insecticides and fungicides and may have their flora altered by such treatment.

- **Removal of microorganisms**

  Thorough washing of fruits serves to remove not only dirt and hence casual contaminating microorganisms but also poisonous sprays. Washing may be with water, detergent solutions, or even bactericidal solutions such as chlorinated water. Trimming also removes microorganisms. Clear fruit juices may be sterilized by filtration.

- **Use of heat**

  Fruits seldom are blanched before other processing because blanching causes excessive physical damage.

  In general, the more acid the fruit, the less heat required for its preservation. Similar principles are involved in canning fruit juices.

- **Use of low temperature**

  A few fruits, such as apples, can be preserved for a limited time in common or cellar storage, but controlled lower temperatures usually are employed during most of the storage period of fruits.

Chilling

Each fruit has its own optimal temperature and relative humidity for chilling storage; even varieties of the same fruit may differ in their requirements. Fruits have been treated with various chemicals before or during storage to aid in their preservation.

Freezing

The surfaces of fruits contain the natural surface flora plus contaminants from soil and water. Any spoiled parts that are present will add molds or yeasts. During preparation of fruit for freezing, undesirable changes may takes place, such as darkening, deterioration in flavor, and spoilage by microorganisms, especially molds.

Numbers of viable microorganisms in frozen fruits are considerably lower than in frozen vegetables. Large numbers of mold hyphae may be indicative of the freezing of inferior fruit that included rotten parts.

- **Drying**

  An occasional sample may contain high numbers of mold spores, indicating that growth and sporulation of molds has taken place on the fruit before or after dehydration. Alkali treatment, sulphuring, blanching, and pasteurization reduce numbers of microorganisms.

- **Use of preservatives**

  Where it was noted that chemicals have been applied to fruits chiefly as a dip or spray or impregnated in wrapper for the fruits. Most of the chemical preservatives mentioned have been primarily antifungal in purpose.

  Green olives are the only fruits which are preserved on a commercial scale with assistance from an acid fermentation. Locally, other fermented fruits sometimes are prepared, such as fermented green tomatoes and Rumanian preserved apples. In all these products the lactic acid fermentation is of chief importance.

7.7 Spoilage

The deterioration of raw vegetables and fruits may result from physical factors, action of their own enzymes, microbial action, or combinations of these agencies. Mechanical damage resulting from action of animals, birds, or insects or from bruising, wounding, bursting, cutting, freezing, desiccation, or other mishandling may predispose toward increased enzymatic action or the entrance and growth of microorganisms. Previous damage by plant pathogens may make the part of the plant used as food unfit for consumption or may open the way make for growth of saprophytes and spoilage by them. Contact with spoiling fruits and vegetables may bring about transfer of organisms, causing spoilage and increasing the wastage. Improper environmental conditions during harvesting, transit, storage, and marketing may favor spoilage.

- **General types of microbial spoilage**

The most common or predominant type of spoilage varies not only with the kind of fruit or vegetable but also to some extent with the variety. The most commonly occurring types of spoilage are as follows:

1. **Bacterial soft rot**, caused by Erwinia carotovora and related species, which are fermenters of pectins. Pseudomonas marginalis and clostridium and bacilius spp. Have also been isolated from these rots. It results in a water soaked appearance, a soft, mushy, consistency, and often a bad odor.
2. **Gray mold rot**, caused by species of botrytis, e.g., B. cinerea, a name derived from the gray mycelium of the mold. It is favoured by high humidity and a warm temperature.
3. **Alternaria rots**, caused by alternaria tenuis and other species. Area become greenish brown early in the growth of the mold and later turn to brown or black spots.
4. **Rhizopus soft rot**, caused by species of rhizopus, e.g., stolonifer. A rot results that often is soft and mushy. The cottony growth of the mold with small, black dots of sporangia often covers masses of the foods.
5. **Anthracnose**, usually caused by collectotrichum lindemuthianum, C.coccodes, and other species. The defect is a spotting of leaves and fruits seedpods.
6. **Blue mold rot**, caused by species of penicillium digitatum and other species. The bluish green colour that gives the rot its name results from the masses of spores of the mold.
7. **Downy mildew**, caused by species of phytophthora, bremia, and other genera. The molds grow in white, woolly masses.
8. **Watery soft rot**, caused chiefly by sclerotinia sclerotiorum, is found mostly in vegetables.
9. **Stem end rots**, caused by species of molds of several genera, e.g., diplodia, alternaria, phomopsis, fusarium, and others involve the stem ends of fruits.
10. **Black mould rot**, caused by asergillus niger. The rot gets its name from the dark brown to black masses of spores of the mold, termed “smut” by the layperson.
11. **Black rots**, often caused by species of alternaria but sometimes of ceratostomella, physalospora, and other genera.
12. **Pink mold rot**, caused by pink spored trichothecium roseum.
13. **Fusarium rots**, a variety of types of rots caused by species of fusarium.
14. **Green mold rot**, caused usually by species of cladosporium but sometimes by other green spored molds, e.g., trichoderma.
15. **Brown rot**, caused chiefly by sclerotinia species.
16. **Sliminess or Souring**, caused by saprophytic bacteria in piled. Wet, heating vegetables.

7.7.1 Spoilages of fruit and vegetable juices.

Juices may be squeezed directly from fruits or vegetables, may be squeezed from macerated or crushed material so as to include a considerable amount of pulp, or may be extracted by water, e.g., prune juice. These juices may be used in their natural concentration or may be concentrated by evaporation or freezing, and may be preserved by canning, freezing, or drying.

The pH ranging from about 2.4 for lemon or cranberry juice up to 4.2 for tomato juice, and all contain sugars, the amounts varying from about 2 percent in lemon juice up to almost 17 percent in some samples of grape juice. Although molds can and do grow on the surface of such juices if the juices are exposed to air, the high moisture content favors the faster growing yeasts and bacteria.

In addition to the usual alcoholic fermentation, fruit juices may undergo other changes caused by microorganisms: (1) the lactic acid fermentation of sugars, mostly by hetero fermentative lactic acid bacteria such as lactobacillus pastorianus, L. brevis, and leuconostoc mesenteroides in apple or pear juice and by nomofer mentative lactic acid bacteria such as lactobacillus arabinosus. L. leichmanii, and microbacterium,(2) the fermentation of organic acids of the juice by lactic acid bacteria, e.g., lactobacillus pastorianus, malic acid to lactic and succinic acids, quinic acid to dehydroshikimic acid, and citric acid to lactic and acetic acids,(3) slime production by Leuconostoc mesenteroides, lactobacillus brevis, and L. plantarum in apple juice and by L.plantarum and streptococci in grape juice.

7.8. Question

1. Discuss the contamination of fruits and vegetables.
2. What is hydro cooling?
3. Write notes on the use of low temperature in the preservation of vegetables.
4. Write notes on the addition of preservatives to vegetables.
5. Discuss the preservation of fruits and fruit products.
6. Give the general types of microbial spoilage of fruits and vegetables.
7. List any five market diseases of fruits and vegetables
8. Write notes on the spoilage of fruit and vegetable juices.
9. List the spoilage microorganisms generally present in fruit juices.
10. Give the causal organism and symptoms of
    a. Black mold rot
    b. Blue mold rot
    c. Watery soft rot
    d. Grey mold rot
    e. Anthracnose

7.9. Suggestion for reading

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UNIT VIII – MICROBIOLOGY OF CEREALS AND CEREAL PRODUCTS

8.1. Introduction
8.2. Objectives
8.3. Importance of cereals in human life
8.4. Mycotoxin
8.5. Prevention of mold and mycotoxin
8.6. Spoilage of cereals
8.7. Question
8.8. Suggestion for reading

8.1. INTRODUCTION

Cereals and cereal products are significant and important human food resources and livestock feeds worldwide. Cereal grains and legumes are food staples in many, if not most, countries and cultures and are the raw materials of many of our foods and certain beverages. The main cereal grains used for foods include corn (maize), wheat, barley, rice, oats, rye, millet, and sorghum. Soybeans are not a cereal product, but rather, are legumes or a pulse, but are often considered with cereals because of their importance as a food source.

8.2. OBJECTIVES

After going through this unit, you should be able to:

- Discuss about contamination of cereals
- Preservation methods of cereals

8.3. Importance of cereals in human life Cereal products derived from cereal grains include wheat, rye, and oat flours and semolina, cornmeal, corn grits, doughs, breads, breakfast cereals, pasta, snack foods, dry mixes, cakes, pastries, and tortillas. In addition, cereal products are used as ingredients in numerous products, such as batters and coatings, thickeners and sweeteners, processed meats, infant foods, confectionary products, and beverages such as beer Because of their extensive use as human foods and livestock feeds, the microbiology and safety of cereal grains and cereal products is a very important area. The sources of microbial contamination of cereals are many, but all are traceable to the environment in which grains are grown, handled, and processed. Microorganisms that contaminate cereal grains may come from air, dust, soil, water, insects, rodents, birds, animals, humans, storage and

Table 1. Major Storage Fungi and the Moisture Contents of Commodities at Which Mold Invasion May Occur

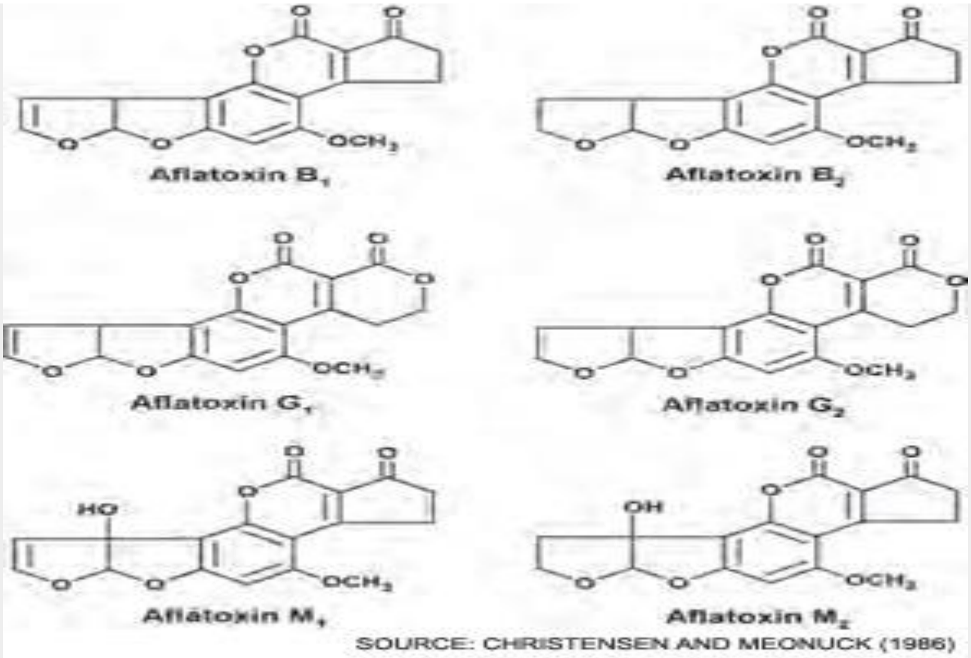
MAJOR STORAGE FUNGI	COMMODITY	MOISTURE (%)
Aspergillus restrictus (blue eye)	Starchy cereals	14.0-14.5
	Soybeans	12.0-12.5
	Sunflower, safflower, peanuts	8.5-9.0
Eurotium glaucus (blue eye)	Starchy cereals	14.5-15.0
	Soybeans	12.5-13.0
	Sunflower, safflower, peanuts	9.0-9.5
A. candidus	Starchy cereals	15.5-16.0
	Soybeans	14.5-15.0
	Sunflower	9.0-9.5
A. ochraceus	Starchy cereals	15.5-16.0
	Soybeans	14.5-15.0
	Sunflower	9.0-9.5
A. flavus	Starchy cereals	17.0-18.0
	Soybeans	17.0-17.5
Penicillium (blue eye in corn)	Starch grains	16.5-20.0
	Soybeans	17.0-20.0
	Sunflower	10.0-15.0

SOURCE:CHRISTNSEN AND MEONUCK (1986)

NOTES

shipping containers, and handling and processing equipment. Many factors that are a part of the environment influence microbial contamination of cereals, including rainfall, drought, Humidity, temperature, sunlight, frost, soil conditions, wind, insect, bird and rodent activity, harvesting equipment, use of chemicals in production versus organic production, storage and handling, and moisture control. The microflora of cereals and cereal products is varied and includes molds, yeasts, bacteria (psychrotrophic, mesophilic, and thermophilic/thermoduric), lactic acid bacteria, rope-forming bacteria (BACILLUS SPP.), bacterial pathogens, coliforms, and Enterococci. Bacterial pathogens that contaminate cereal grains and cereal products and cause problems include BACILLUS CEREUS, CLOSTRIDIUM BOTULINUM, CLOSTRIDIUM PERFRINGENS, ESCHERICHIA COLI, *Salmonella*, And STAPHYLOCOCCUS AUREUS. Coliforms and enterococci also occur as indicators of unsanitary handling and processing conditions and possible fecal contamination.

Bacteria are frequent surface contaminants of cereal grains. For bacteria to grow in cereal grains, they require high moisture or water activity (a_w) in equilibrium, with high relative humidity. Generally, bacteria are not significantly involved in the spoilage of dry grain and become a spoilage factor only after extensive deterioration of the grain has occurred and high moisture conditions exist. However, bacterial pathogens and spoilage bacteria, such as spore-forming bacteria that cause ropiness in bread, may survive and carry through to processed products and become problems. Lactic acid bacteria may also be present in the raw grain and carry over into flour and cornmeal and spoil doughs prepared with them. Yeasts present on cereal grains may also carry through into processed products. The main spoilage organisms in cereal grains, however, are molds.



n
The chemical structure of aflatoxin.

There are more than 150 species of filamentous fungi and yeasts on cereal grains. But again, the most important of these are the filamentous fungi or molds. The filamentous fungi that occur on cereal grains are divided into two groups, depending on when they predominate in grain in relation to available moisture in the grain. These groups have been referred to as field fungi and storage fungi. Field fungi invade grain in the field when the grain is high in moisture (18 to 30%, i.e., at high a_w) and at high relative humidities (90 to 100%). Field fungi include species of ALTERNARIA, CLADOSPORIUM, FUSARIUM, And HELMINTHOSPORIUM. Storage fungi invade grain in storage at lower moisture contents (14 to 16%), lower a_w and lower relative humidities (65 to 90%). These main storage fungi are species of Eurotium, Aspergillus, and Penicillium. To prevent spoilage by storage fungi, the moisture content of starchy cereal grains should be below 14.0%, soybeans 12.0%, and other oilseeds, such as peanuts, and sunflower seeds, 8.5%. Certain molds, such as EUROTIUMGLAUCUS, may initiate growth at low a_w and moisture contents (i.e., 15 to 16% moisture) and through their respiration increase a_w and raise the moisture content, facilitating moulds to grow, thus ultimately leading to spoilage.

The major effects of fungal deterioration of grains include decreased germination, discoloration, development of visible mold growth, musty or sour odors, dry matter loss and nutritional heating, caking, and the potential for production of mycotoxins in the grain. Decreased germination of the grain occurs when storage fungi invade the germs or embryos of the grain kernel. The embryos are weakened and die as the storage fungi attack and parasitize the embryo to utilize its oils and other nutrients. Decreased germination caused by storage fungi usually precedes discoloration. However, discoloration can be caused by both field and storage fungi and can result in brown to black germs in wheat and corn

and "blue eye" in corn, due to the presence of blue ASPERGILLUS and PENICILLIUM species. Musty odors may become apparent before mold growth becomes visible and is an early warning of mold activity, as is heating

Table 2. Mycotoxins of Greatest Concern in Grain and the Molds That Produce Them

MYCOTOXINS	MOLDS
Aflatoxins	*Aspergillus flavus, A. parasiticus, A. nomius*
Ochratoxin	*Aspergillus ochraceus, A. niger, Penicillium verrucosum*
Fumonisins	*Fusarium verticillioides (moniliforme) F. proliferatum, F. subglutinans*
Moniliformin	*F. proliferatum, F. subglutinans*
Deoxynivalenol (DON, vomitoxin)	*Fusarium graminearum, F. culmorum, F. crookwellense*
Zearalenone	*Fusarium graminearum, F. culmorum, F. crookwellense*

SOURCE: CHRISTENSEN AND MEONUCK (1986)

Mycotoxins of Greatest Concern in Grain and the Molds That Produce Them

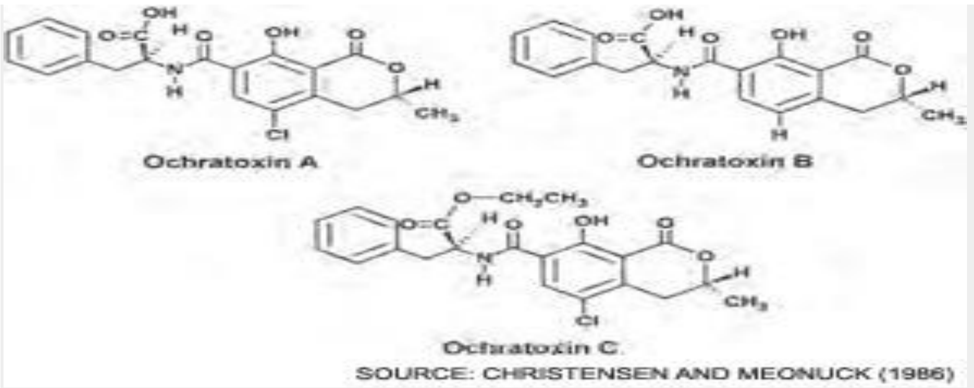
Heating often starts in the fine materials or dust associated with the grain and is due to the growth of storage fungi. If sufficient heating occurs, the grain becomes dark and blackened. Further growth of storage fungi may result in surface growth and binding of the grain kernels together by mold hyphae, which is manifested as caking of the grain (i.e., large masses of the kernels bound together). By the time caking occurs, mold growth has become extensive and the grain is in advanced stages of decay. At this point the moisture content of the grain is increasing due to the respiration of the molds, and growth of yeasts and bacteria may also occur.

8.4. Mycotoxins

- The word mycotoxin is derived from the Greek word mykes, meaning fungus or mold, and the Latin word toxicum, poison or toxin. Thus, mycotoxin is a general term meaning fungus poison or mold toxin. Mycotoxins are toxic secondary metabolites produced by filamentous microfungi or molds. These secondary metabolites are distinguished from primary metabolites because they are not required for the growth of the fungus and have no apparent purpose in the metabolism of the organism. It has been speculated that mycotoxins are waste products or defense mechanisms. Mycotoxins are toxic and harmful in varying degrees to humans and animals, and may contaminate cereal grains in the field and in storage. Mycotoxins are stable compounds that resist destruction by

food-processing methods and may carry through and contaminate finished processed foods.

- There are numerous specific mycotoxins that may contaminate cereal grains, such as aflatoxins, ochratoxin, fumonisins, moniliformin, deoxynivalenol, T-2 toxin, and zearalenone. Mycotoxin research began in 1960 with the outbreak of Turkey "X" disease in England, where thousands of turkey poults and other young farm animals were lost due to poisoning by a fungal metabolite produced by ASPERGILLUSFLAVUS in peanut meal. The toxic substance was called aflatoxin (A. FLAVUS TOXIN). Since 1960, many other toxic mold metabolites have been described. Those mycotoxins currently thought to be most important in cereal grains are listed in Table 2 (see p. 28) along with the molds that produce them.



The chemical structure of ochratoxin.

Mycotoxins exhibit a range of toxicological properties, including acute toxicity or poisoning, which often results in death, and subacute or chronic toxicity, which may not result in death directly but which gradually weakens and lowers the general health of an animal or human due to effects on the immune system. Chronic toxicity may result in greater susceptibility to secondary bacterial infections. Some mycotoxins are carcinogenic and may cause cancers; some are mutagenic and are capable of causing mutations; they may also be teratogenic and embryo toxic, causing deformities and death in developing embryos.

8.5. MEDIA, METHODS FOR MOLDS AND MYCOTOXINS

- There are a variety of media and methods for detection and enumeration of molds in cereal products. Many media are recommended by the International Commission on Food Mycology (ICFM) as well as given in the Compendium of Methods for the Microbiological Examination of Foods

- Dichloran rose Bengal chloramphenicol (DRBC) agar is recommended as a general-purpose medium for direct plating of grain kernels and for plate counts of flours, meals, and processed products for total counts. Dichloran with 18% glycerol (DG18) is also recommended for these uses, especially for direct plating kernels for xerophilicmolds, which prefer low a_w and dry conditions. For plating dry grains and cereal products, DG18 may actually be better than DRBC and the medium of choice.

Table 3. Methods for Detection of Mycotoxins

MYCOTOXINS	METHODS
Aflatoxins	TLC, HPLC, ELISA, immunoaffinity column
Ochratoxin	TLC, HPLC, ELISA, immunoaffinity column
Fumonisins	HPLC, ELISA, immunoaffinity column
Moniliformin	HPLC
Deoxynivalenol	GC, HPLC, ELISA, immunoaffinity column
Zearalenone	TLC, HPLC, ELISA, immunoaffinity column

SOURCE: CHRISTENSEN AND MEONUCK (1986)

Methods for Detection of Mycotoxins

- Two differential media may also be used for detection and enumeration of specific molds in cereals. ASPERGILLUSFLAVUS–parasiticus agar (AFPA) can be used as a differential medium for direct plating of kernels and plate counts of A. FLAVUS and A. PARASITICUS. Czapek agar with iprodione and dichloran added (CZID) is widely used as a differential medium for detecting and enumerating FUSARIUM species from cereals. The simplest way to evaluate the internal microflora of seeds and kernels is the direct plating method, which involves surface sanitizing seeds or kernels in full strength or 50% household bleach for one minute to kill surface microflora. The kernels or seeds are then rinsed in sterile distilled water and dried on sterile paper towels.

- The seeds or kernels are then placed directly on an agar surface in a Petri dish and incubated at 25 to 30°C to allow molds located in the interior of the seed or kernel to grow out. The number of kernels with internal mold is counted and the results are expressed as a percentage of infected kernels. The amount of internal infection of the grain is an indicator of quality and storability of the grain. The technique can also give some information about the safety of the grain if AFPA or CZID have been used, indicating whether or not potentially toxic A. FLAVUS, A. PARASITICUS, or FUSARIUM species are present.

- Methods for detecting mycotoxins are summarized in Table 3 (above). Chromatographic methods have been used from the beginning of mycotoxin research and are still used for detecting, quantifying, and confirming the presence of mycotoxins. These methods have evolved, been improved, and have become more sophisticated. Chromatographic methods in use include thin-layer chromatography, high-performance liquid chromatography, liquid chromatography combined with mass spectrometry, gas chromatography, and gas chromatography combined with mass spectrometry.

- Various detection methods, such as fluorescence, ultraviolet absorption, and others have been combined with chromatographic methods. New methods based on the production of antibodies specific for individual mycotoxins have also been developed and include enzyme-linked immunosorbent assays and immunoaffinity columns. These methods allow for specific and precise detection and quantification of specific mycotoxins. This has lead to test kits for mycotoxins which are rapid and simple to use and can be used in the field, country elevators, grain-buying stations, feed mills, and processing plants.

8.6 Contamination, preservation and spoilage of cereals &cereal products:

- The exteriors of harvested grains retains some of the natural flora they had while growing plus contamination from soil, insects & other sources.
- Freshly harvested grains contain loads of a few thousand to millions of bacteria /gm and mold spores
- Bacteria are mostly in the families Pseudomonas, Micrococci, Lactobacilli and Bacilli.
- Scouring & washing the grains remove some of the microorganisms, but most of the microorganisms are removed with the outer portions of the grains during milling. The milling processes especially bleaching reduce no. of organisms.
  Corn meal and flour contain several hundred to several thousand bacteria and mold per gram. Species of fusarium&penicillum are dominant molds. Because of the incubation in a moist conditions , malts contain high numbers of bacteria , usually in the millions per gram. The surface of freshly baked bread is free of viable microorganisms but is subject to contamination by molds spores from the air during cooling & before wrapping .cakes are similarly subject to contamination .spores of bacteria able to cause repines in bread will survive the baking process. The contamination of cereals grains products with molds has become a significant concern because of the presence of mycotoxin.
- But there then is possibility of contamination during other procedures such as blending & conditioning.

- Bacteria in wheat flour include spores of Bacillus, coliform bacteria, and few representatives of the genera Achromobacter ,Flavobacterium , Sarcina ,Micrococcus and Serratia. Mold spores are of aspergilli, penicillia, alternaria&cladosporium.patent flours usually give lower counts than straight or clear & no. decreases with storage of flour.
- Higher counts usually are obtained on prepared flours (8000 to 12000 per gram on the average) & whole-wheat flours, which contain also the outer parts of wheat.
- The need to reduce contamination by mold and to avoid conditions which allow their growth is emphasized because of frequent isolation of Aspergillusflavus, which can produce aflatoxin.

Some commonly isolated molds such as fusaria&penicillia are undesirable since they are capable of producing mycotoxins.

- Most cereals and cereal products have such a low moisture content that there is little difficulty in preventing the growth of microorganisms as long as the foods are kept dry.
- Such materials are stored in bulk or in containers to keep out vermin, resist fire and rapid changes in temperature and hence increase in moisture.
- The storage temp. Of about 4.4 to 7.2c is recommended for the dry products.

Many bakery products eg. Bread, rolls, cakes, pastries &canned mixes contain enough moisture to be subject to spoilage unless special preservative methods are employed

- Asepsis: improperly sanitized equipment may be source of rope bacteria and the acid –forming bacteria that cause sourness of dough. bread ,cakes and other baked products may be subject to spoilage by molds should be protected against contamination by mold spores
- Use of heat: bakery products may be sold unbaked, partially baked or fully baked .the complete baking process destroys all the bacterial cells, yeasts ,mold spores but not spores of rope –forming bacteria. they can survive during heat so unbaked products are kept for short period or kept cool during longer storage of time.
- Use of low temp. : baked products should be kept under cool conditions or refrigerated in home for the prevention of food spoilage. These can be stored for months in the frozen conditions.
- Use of chemical products : a large no. of preservatives have been employed ,particularly as mold inhibitors , in breads , rolls , cakes . Sodium and calcium propionate , sodium diacetate and sorbates are used extensively .acidification of dough with acetic acid has been used to combat rope.
- Use of irradiation : In bakeries , ultraviolet rays have been to destroy or reduce numbers of mold bacteria in dough and proof rooms, on the knives of slicing machine , on the surface of breads

,cakes .ionizing radiations , gamma and cathode rays have been applied experimentally for the preservation of baking goods.

Cereals grains, meals &flours made from them should not be subject to spoilage if are stored or kept properly because their moisture content is too low to support even the growth of molds. Now different cereal products are discussed below:

1. Cereal grains &meals :

A little moisture will result in growth of molds at the surface , where air is available. A wet mash of the meals will under go an acid fermentation by lactic acid and coliform bacteria normally present on the surface of plants. This may be followed by the alcoholic fermentation by yeasts as soon as the acidity is increased enough to favor them . The major factors included in the spoilage of stored grain by molds include microbial content , moisture levels above 12 to 13 %, physical damage & temperature. Most common species of molds are Aspergillus , Penicillium and Fusarium.thesemolds can produce mycotoxins .

2. Flour :

Dry cleaning and washing , milling & sifting of flour reduce the content of m.o., but important kinds still are represented in whole –grain flours e.g. and the spoilage would be similar to that described for cereal grains and meals. Slight moistening of white flour brings about spoilage by molds. Because of the variations in microbial content of different lots of flour , the type of spoilage in a flour paste is difficult to predict. If acid –forming bacteria are present , an acid fermentation begins , followed by alcoholic fermentation by yeasts if they are there and then acetic acid by Acetobacter species. In the absence oflactics and coliforms , micrococci have been found to acidify the paste .

3. Bread :

The fermentation taking place in the dough for various kinds is due to microorganisms are desirable and even necessary in making certain kind of bread .the acid fermentation bylacticsand coliform bacteria that is normal in flour pastes or dough may be too extensive if too much time is permitted, with the result that the dough bread made from it may be too 'sour'. Excessive growth of proteolytic bacteria during this period may destroy some of the gas –holding capacity so essential duringthe rising of the dough & produce a sticky dough. The chief types of microbial spoilage of baked bread have been moldiness and ropiness , usually termed "mold" & "rope".

4. Mold:

Molds are the most common and hence the most important cause of the spoilage of bread and most bakery products. The temp. Attained in the baking procedures usually are high enough to kill all the molds spores in and on the loaf. They can come from the air during cooling, from handling or from wrappers .chief molds involved in the spoilage of bread are "bread mold", rhizopusnigricanswith its white cottony mycelium and black dots of sporangia; the green –sporedPenicilliumexpansum;aspergillus Niger with

its greenish or purplish –brown conidial heads and yellow pigment diffusing into the bread. Mold spoilage is favored by - heavy contamination due to air circulation. During slicing when there is more air is introduced into the loaf .

- Wrapping, especially if the bread is warm when wrapped & storage in a warm , humid place .
- Rope – ropiness of bread is fairly common in home baked bread, especially during hot weather, but it is in commercially baked bread because of preventive measures now employed .ropiness is caused by a mucoid variant of Bacillus subtilis .the spores of these species can withstand the temperature of the bread during baking, which does not exceed 100℃ , can germinate &can grow in the loaf if conditions are favorable. The area of ropiness is yellow to brown in color & is soft, sticky to touch. In one stage the slimy material can be drawn out into long threads when the bread is broken and pulled apart. First the odour is evident, then discoloration and finally softening of the crumb, with stickness and stringiness.
- Red or bloody" ,bread is striking in appearance but rare in occurrence .the red color results from the growth of pigmented bacteria, usually serratiamarcescens, an organism that often is brilliantly red on starchy foods. Molds such asMoniliaSitophilamay impart a pink to red color to bread .a red color in the crumb of dark bread has been caused byOidiumGeotrichum.
- Chalky bread : chalky bread is so named because of white , chalklike spots .the defects has been blamed on the growth of yeast like fungi, Endomycopsisfibuligeraand Trichosporon variable.

Cakes and other bakery products: molds are main cause of spoilage in cakes .the deterioration of bread , cakes , pies and other bakery products caused "staling" is due to physical damage during holding and not to microorganisms. Freezing and storage in the frozen conditions is effective in preventing these changes.

Macaroni and tapioca: swelling of moist macaroni has been reported to be caused by gas production by bacteria resembling Enterobacter cloacae .during the drying of macaroni on paper a mold of the genus Monilia has been found responsible for purple streak at the contact points with the paper .tapioca prepared from the root starch of cassava will spoil if moistened .spoilage by an orange –pigmented, starch –hydrolyzing bacteria has been shown.

8.8 Suggested Readings

1. Leistner, L., Rodel, W., and Krispien, K. (1981) Microbiology of meat and meat products in high- and intermediate-moisture ranges.
2. Classification of Lactobacillus divergens, Lactobacillus piscicola and some catalase-negative. asporogenous, rod-shaped bacteria from poultry in a new genus. Carnobacterium.

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UNIT IX – MICROBIOLOGY OF FLESHY FOODS, POULTRY AND FISH – CONTAMINATION, SPOILAGE, PRESERVATION AND CONTROL

9.1. Introduction
9.2. Objectives
9.3. Microbiology of poultry
9.4. Microbiology of Fish
9.5 Questions
9.6Suggested Readings

9.1. INTRODUCTION

The microbiological profile of meat products presented to the consumers is the sum total of the slaughtered animal health, conditions under which it was reared, quality of slaughtering, processing, packaging and conditions under which the meat was stored. Meat pathogens can cause self-limiting human enteric diseases or systemic and fatal infections of the immunocompromised, the elderly and the young. Meat can act as an ideal substrate for microbial proliferation. Major meat associated pathogenic bacteria include clostridium perfringens, staphylococcus aureus, salmonella spp, pathogenic strains of escherichia coli, campylobacter spp, yersinia enterocolitica, listeria monocytogenes and aeromonashydrophila.

9.2. OBJECTIVES

After going through this unit, you should be able to:

- Discuss about microbiology of poultry
- Contamination and spoilage of fleshy foods
- Preservation and control of fleshy foods

9.3. MICROBIOLOGY OF POULTRY

Meat, fish and poultry constitute the major portion of man’s food in many parts of the world. There is no doubt that most people prefer fresh fish or meat to products that have been preserved and processed. However, flesh foods, particularly fish are vulnerable to biochemical changes that take place during refrigeration or storageand, therefore, do not fare well as compared to other agricultural products. Rodents, insects, molds and yeast, as well as bacteria cause wastage at various stages in the post-harvest period in flesh foods.

9.3.1 Contamination of meat

Pre-Slaughter Handling Effects on Meat Quality Handling during the pre-slaughter period (that period after the animal is last removed from feed) is

thought to have an effect on beef quality mainly through an effect on the ultimate pH of the beef by means of glycogen depleting events during this period.

The different glycogen depleting events have an additive effect so that an animal that started the pre-slaughter period with a muscle glycogen at only 1% would have a muscle glycogen of 0.4% following a 0.6% glycogen depleting event, while an animal that started with 1.8% glycogen would have a muscle glycogen level of 1.2% following the same event (Jacobson, 1999).

This means that the same event has no effect on the ultimate pH of the latter animal but results in the former animal having a significantly elevated ultimate PH. If however, the latter animal was exposed to an additional 0.8% glycogen depleting event following the initial event, then it would have only 0.4% of glycogen at slaughter and would also have a significantly elevated ultimate PH. For most purposes an elevated ultimate PH results in beef of lower overall quality although some of the individual quality characteristics may be improved for certain purposes.

Relative to beef with a normal rested ultimate pH of about 5.5, beef with an elevated ultimate PH will be characterized by:- A darker color, especially when the ultimate PH is above about 6.2, and this effect has given rise to the term "dark-cutting beef", A blander and usually less acceptable flavor.

Poultry meat like meat of other animals is also susceptible to contamination by various sources. Contamination of skin and lining of the body cavity take place during various processing operations. The organisms of great importance in poultry are *Salmonella* spp. and *Campylobacter jejuni.* Several Gram negative psychrotropicbacteria *viz.*, *Pseudomonas*, *Acenitobacter* and *Flavobacterium* have also been isolated from poultry carasses. Ground turkey also may carry fecal streptococci. It is important to freeze the poultry fast in order to keep it in good condition for several months. Freezing further reduces the number of microorganisms in the poultry meat provided the temperature is maintained quite low (-18 ° C or below).

9.3.2. Spoilage of meat

9.3.2.1. Microorganisms Associated with Meat during Processing

Meat spoilages indicate (a) color changes (b) textural changes and (c) development of off-flavour or off-odor or slime as a result of microbial growth. *Salmonella* is the primary microbial challenge for poultry. The primary microbial to the beef industry is *Escherichia coli* O157: H7. *Listeria*, which is an adulterant with zero tolerance, is the major problem for ready to eat meat products. Treatment with organic acids, hot water steam carcass pasteurization and steam carcass vacuuming, trisodium phosphate, acidified sodium chlorite, chlorine dioxide, lactoferrins, peroxyacetic acid, sodium lactate, sodium acetate and sodium diacetate, ozone and radiation have been used as microbial decontaminants during meat processing operations. Carcass washing with hot water of 80°C for 10 seconds can reduce microbial loads by 2 logs. Current regulatory policies and inspection in the meat industry include the HACCP (Hazard Analysis Critical Control Point) food safety system with an objective to provide safe

food for consumption and prevent chemical, physical and biological hazards.

Gram-negative bacteria (Aerobes)

Neisseriaceae: *Psychrobacterimmobilis, P. phenylpyruvica, Acinetobacter* spp.*, A. twoffii, A. Johnsonii,*
Pseudomonadaceae: *Pseudomonas fluorescens, P. lundensis, P. fragi, P. putida*

Gram-positive bacteria:

Brochothrixthermosphacta, Kurthiazophii, Staphylococcus spp., Clostridium estertheticum, Clostridium frigidicarnis, Clostridium casigenes, Clostridium algidixylanolyticum sp*. nov.*

9.3.2.2. Fresh Meat

In contrast to fruits and vegetables, meats are composed mainly of protein and fats rather than carbohydrates. Water content is 71–76% and therefore moisture is not an issue except for spoilage microbes on cured meats. Muscles of healthy animals do not contain any bacteria or fungi but as soon as animals are slaughtered, meat is exposed to contaminants and good sanitation practices are essential to produce high quality meats. The number of spoilage organisms on meat just after slaughter is a critical factor in determining shelf life. The surface of beef carcasses may contain anywhere from 10^1 to 10^7 cfu/cm2, most of which are psychrotrophic bacteria. Chopping and grinding of meats can increase the microbial load as more surface area is exposed and more water and nutrients become available. A large variety of microbes are commonly found on fresh meat, but different microbes become dominant during spoilage of different meats depending on pH, composition and texture of processed meats, temperature and packaging atmosphere. *Pseudomonas* spp. is the predominant spoilage bacteria in aerobically stored raw meat and poultry. Once the initial low levels of glucose are depleted by various microbes, *Pseudomonas* has an advantage because it can catabolize gluconates and amino acids more readily than other microbes. Break down of these compounds results in production of malodorous sulfides, ammonia, and amines, including the biogenic amines putrescine and cadaverine. Dark, firm and dry meat with a relatively high pH of 6.0 spoils more rapidly because deamination of amino acids starts earlier. *Shewanellaputrefaciens* does not grow on meat at pH<6.0 but can produce sulfides and ammonia even when glucose is still available. These sulfides not only smell bad but also cause color changes in meat, and therefore Shewanella has a high spoilage potential on fresh, high pH meats stored aerobically even when it is not a dominant microbe. *Brochothrixthermosphacta* is often a significant spoilage organism on fresh meat stored aerobically at refrigeration temperatures. *Enterobacteriaceae*, particularly species of *Serratia*, *Enterobacter*, and *Hafnia*, are major causes of spoilage in vacuum-packed, high pH fresh meats. These organisms are facultative

anaerobes that produce organic acids, hydrogen sulfide and greening of meats.

9.3.2.3. Processed Meat

Addition of sodium chloride, nitrites and/or nitrates, along with various other seasonings, emulsifiers and preservatives to ground or whole muscle meats changes the environment significantly and also the spoilage flora of processed meats. Dried and dry-fermented meats generally do not support microbial growth although process deviations may allow growth of some organisms. Spoilage organisms can grow on fresh and cooked cured meats, so they are best stored chilled, under a vacuum or modified atmosphere. *Pseudomonas* spp. are not usually important causes of spoilage in processed meats because of their sensitivity to curing salts and heat pasteurization and their inability to grow well in meats packed with a vacuum or high carbon dioxide atmosphere. However, when packages have been opened and there has been insufficient curing, these bacteria may spoil refrigerated processed meats. Some cold- and salt tolerant *Enterobacteriaceae* have been found to cause spoilage in some specific processed meats, such as ham or bacon.

Lactic acid bacteria (LAB) is the group of bacteria primarily associated with spoilage of processed meats. They produce sour off-flavors, gas, slime, and greening, and this spoilage may be more severe than in fresh meat because of the presence of added carbohydrates. Competitive ability of different LAB strains is related to pH and water activity of the meat, cooking and storage temperatures and oxygen and carbon dioxide levels. Sporeformers (*Clostridium* and *Bacillus*) are usually not a spoilage problem in processed meats because of the presence of nitrite and other curing salts. However, faulty cooking/cooling procedures, including long cooling periods and temperature abuse, has allowed growth of these organisms in some cases. Spores of these organisms may be introduced with spices or other ingredients. Yeasts cause some spoilage in processed meats but are generally only important when sulfite is used as a preservative or when meats have been irradiated or are stored aerobically in the cold. Slime may be produced along with vinegary or malty off-odors in some sausages.

9.3.2.4. Spoilage under aerobic condition

1.) Surface slime, caused by *Pseudomonas acinetobacter*, *Moraxella alcaligenes Streptococcus*, *Leuconostuoc*, *Bacillus* and *Micrococcus.*

2.) Change in colour of meat pigment. The red colour of meat may be changed to shades of green, brown or grey by *Lactobacillus* and *Leconostocs* spp.

3.) Changes in fat. The unsaturated fat in meat gets oxidized by lypolitic bacteria which produce off odours due to hydrolysis of fats and production of aldehydes and acids. This type of spoilage is caused by lypolitic *Pseudomonas*, Achromobacter and yeast.

4.) Surface color change. The red pigment producing bacteria, *Serratiamarcescens*, caused red spots on meat. Blue color surface is caused by *Pseudomonas syncyanea* and yellow color is caused by *Micrococcus* species.

5.) Off odor and off taste. Volatile acid like formic, acetic, butyric and propionic acid produce sour odor and *Actinomycetes* produce musty or earthy flavor. Yeast also cause sliminess discoloration and off odor and taste defects.

6.) Aerobic mold also cause spoilage in meat. These are stickiness, whiskers, black-spot, white-spot, green patches off odor and off taste.

7.) Spoialage under anerobic condition.

i) Souring is caused by production of formic, acetic, butyric, lactic, succinic and propionic acid.

ii) Putrefaction. It is caused by decomposition of proteins under anaerobic condition by *Clostridium* species. The foul smell is due to production of hydrogen sulphide, mercaptans, indol, scatol, ammonia and amines.

Photographs of spoilage of meat is shown in Figure 9.1

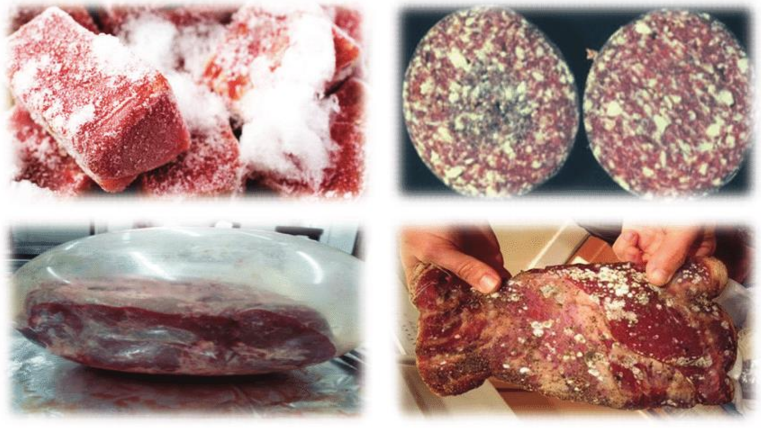


Fig. 9.1 Spoilage of meat

9.3.4. Preservation and storage of meat

There are a number of technologies for the preservation and storage of meat. A brief discussion of these follows hereunder:
9.3.4.1. Cured Meat: Basically, the curing process consists of addition of salt to retard bacterial action and to promote preservation. Curing is confined usually to beef and pork cuts. A cured meat product may be dried (and smoked) and treated with salt, sodium nitrate, sugar and other sweeteners; sometimes spices, garlic, pepper, vinegar and phosphates may also be used.

Salt is a basic ingredient for all curing mixtures. Salt reduces the water content of the product and leads to changes in osmotic pressure which are unfavourable to microbial growth.
This undesirable effect is generally countered by the use of sugar, which counteractssaltiness as well as reduces the hardening effect of salt preventing some of the moisture removal. Sugar also reacts with the amino groups of the protiens to form products of browning reactions. This enhances the flavour of the cured meat. However, excessive browning may occur and impart a burnt flavour to the cured product.

When the curing agents are applied dry to the surface of the meat, the process is called dry curing. When the immersed in the curing agent, it is known as pickling. When brine solution is used, it is called “sweet pickle”. The temperature should be maintained at 30 to 40°F. When the solution is pumped through the vascular system of the meat, it is called vein curing or vascular curing.

When the curing solution is pumped into a ham, it increases its weight, and the ham is to be labelled ‘water added’, it has upto 10 percent more weight than the fresh ham. Addition of the watering curing solution, generally increases the juiciness and flavour of the ham.
Country ham is dry cured, and does not require refrigeration. The curing substance is rebbed into the ham and allowed to cure the meat for approximately one day per pound of ham. The hams are smoked naturally without chemicals, and are allowed to age upto one year. Owing to high salt content, these hams must be soaked and boiled before cooking.
In curing, sugar is used principally to provide flavour. Salt dries out the meat, sodium nitrate and nitrate stabilize the colour pigment so that cured meat retains its redness. Sodium nitrate is a source of nitric oxide, a specific fixative. It is the interaction of nitric oxide with the hemoglobin/myoglobin that forms the stable pigment, methemoglobin. Sometimes smoking of cured ham is done by chemical treatment.

9.3.4.2. Sausage: selection of the appropriate quality of meat is an important first step in the manufacture of sausages. Quality characteristic required for such meat are the chemical and microbiological age of the meat. For manufacture of sausage and the canned meat products, lean skeletal meat is preferred. These two properties are collectively referred to as the binding ability of a meat. Sausage ingredients are called either binder or filter meats.
Binder meat may be from high, medium or low categories, depending on their ability to bind water or emulsify fat. Low bindings meats are those which contain a large proportion of fat, smooth muscle or cardiac muscle tissue. The moisture-protein ratio is important, because in preparing sausage formulations, they provide guidelines in predicting the composition of the finished product.
Sausage are a diverse group of products. They may be ground or emulsion type products. The meat may be essentially ground pork or beef. However, sausage is a generic term that includes all sausage items. They may also be classified according to the meat components. Terms often used to characterize sausage are salami, bologna, wieners, etc.
Ground sausage have discrete meat particles. In emulsion type sausage, fat is emulsified and stabilized by lean components. Both types can be

prepared with the same type of equipment and can be chilled, cured, cooked, dried, frozen or smoked. However, differences in structure of the sausage mass may require different types of handling to various degrees.

The sequence of operations used for processing of sausages is as follows:

1.**Grinding:** meat chunks of variable size and shape with different fat content are put into grinder to form uniform cylinders of fat and lean meat. Particles of lean and fat should be mixed well to obtain a uniform product.

2.Mixing: The cylinders of fat and lean are tumbled in a mixer to achieve uniform distribution of the fat and lean particles. This may then be used for coarse ground sausages or, after emulsification, be converted into emulsion type sausages.

3. Chopping: A chopper consists of a revolving metal bowl in which knife blades rotate on an axle. The blades cut through the revolving meat mass. A chopper is used as a means of batching sausage mix, after which each batch is transferred to an emulsifier to impart desirable texture.

4. Emulsifying: The emulsifying machine is basically comprises grinding and chopping. Larger amounts of meat can be handled rapidly to obtain the desired texture. The meat which is fed into the emulsifier should be uniform.

5. Stuffing: Sausage emulsion or mix is also known as dough, or batter. After coming out of the emulsifier mix into casings. The casings are usually made of cellulose or are of animal origin. The latter are used for stuffing emulsion-type products. The combined piston-pump stuffer usually has a volumetric delivery, and is used for small sausages, and for stuffing uniform weight products.

6. Linking and Typing: After stuffing the casings, the encased mass is tied with thread or fastened with metal clips to produce links. For smaller sausages, the stuffed casings are either twisted or drawn together. Linking may be done by hand, but rarely so in industrialized countries.

7. Smoking and Cooking: The sausage links are draped to form a loop for further processing, e.g. smoking. Alternatively, they may be suspended from a hook. Smoking essentially results in drying and cooking, during which the sausage emulsion is coagulated. The quality of product is determined by temperature, relative, humidity, air flow and its pattern, the time cycle and smoke density. During cooking and smoking, the temperature (internal) rises from about 60 to 70°F to approximately 155 to 160°F. For each 100lbs of sausage, a minimum of 10,000 Btu (thermal requirements) are needed. Air flow patterns have an important role in production performance in terms of size, shape and methods of holding. Smoke density control is essential for the product to be evenly smoked.

8. Chilling: After cooking, the sausages are sprayed with cold water and then chilled by refrigeration. For large batches, chilling is done on a continuous basis by using a brine (6 percent) solution. Brine helps to lower the chilling temperatures and to rapidly chill the product. Further, use of brine prevents the leaching out of salt from the product, or vice versa, i.e., the imbibing of water by the product.

9. Peeling and Packaging: After chilling to achieve an internal temperature of 35 to 40°F, the sausages are peeled to remove cellulosic

casings, usually by machines since hand peeling is slow. Peeled sausages are usually unit packed. Large sausages may be sliced prior to packaging.

Semidry and Dry Sausages: Semidry Sausages: These are made from pork/beef or a mixture of both and generally, have a moisture content of 40 to 45 percent. Some of the semidry sausages have a good shelf life and do not require much refrigeration because:

(a) The cooking process reduces the microbial load.

(b) The high ratio of salt to water acts as a deterrent to microbial growth, and

(c) The low PH also acts as a preservative. Usually the keeping quality is good if the PH is approximately 5.0.

However, sausages stored at refrigeration temperatures have a longer shelf life than those stored at room temperature.

9.3.4.3. Dry Sausages: These differ from semidry sausages in that dry sausage is not cooked and smoking need not necessarily be done. Controlled manufacture of dry sausages is difficult as compared to regular, conventional and semi-dry sausages. The processing time for sausages is quite long (as much as 3 months). The prolonged period of holding makes the product more susceptible to spoilage by, both, chemical and microbial agents. The initial sausage mix should be held under specific controlled refrigeration to establish medium for bacterial culture. When animal casings are used, they should be held for 1/3 or ½ of the dry circle, or until such a time that the dry casing can bear the weight of filling without stretching at the hanging tie.

9.3.4.4. Casings: Preparation of sausages requires casings which, in turn, determine the size and shape of the sausages. The casings must be functionally efficient, i.e., (a) they must be able to withstand and contain the meat mass filling, and (b) they must have shrink and stretch characteristics that allow contraction and expansion of meat mass during processing and storage, and withstand the forces produced during stuffing, linkage and closure.

Two basic materials used for the casings are cellulose or collagen. Regenerated collagen, as well as cloth can also be used. Animal intestines have been traditionally used; however the availability of these limit sausage productions. On the other hand, cellulosic casings can be used as long as the meat supply lasts.

Regenerated collagen casings have many of the physical properties of animal casings combined with the cleanliness of cellulosic casings. Cellulosic casings have good functional properties, such as:

1. Tight packing in of the meat filling is possible, thus reducing the air pockets, and

2. Some fat oozes out of the meat. This fat melts at the higher temperatures used for smoking and seals the surface of the product. This prevents dehydration of the product.

Casings can be closed either with cotton, thread or metal clips.

9.3.4.5. Smoked Meats

These usually refer to products like ham or bacon (pork which has been cured, smoked, and often cooked). The process of smoking has been described previously in this chapter.

In the USA., hams are classified into 2 types based on the internal temperature of the ham which is achieved while smoking. These are either smoked where the temperature is 140 to 147°F, or fully cooked or ready-to-eat (148°F).

While smoking, it is desirable that the internal temperature reaches at least 137°F in order to destroy Trichinella. Some hams (country hams) are subjected to a very long duration of curing. Further such hams are cooked prior to eating and, hence, have minimal risk of infection the consumer with Trichina.

9.3.4.6. Dehydrated Meat

Only a limited amount of dehydrated meat is available as it is mainly imported or used as a provision. Freeze drying is the best method, but it is costly. A steak takes 24 to 30 hours drying time, and on being rehydrated, it tastes and looks much like the fresh item.

9.3.4.7. Frozen Meat

Most of the commercially marketed meat is quick frozen. Freezing halts microbial growth and limits the action of the most destructive spoilage agents. Meats like beef, lamb or mutton are packed and marketed as frozen meats in a big way. Commercial freezing methods are three types like one used for freezing fish: These are:

1. Blast Freezing: Meat is frozen at temperatures as low as -40℃. Large fans blow cold air evenly over the cuts of meat.

2. Plate Freezing: The plate freezers operate at a below -30℃ and consists of a series of refrigeration plates which are pressed against both sides of the thick sections of meat to be frozen.

3. Immersion Freezing: the meat is sealed in packaging material, and then dipped into a sink containing a solution of either common salt or propylene glycerol. The brighter colour of the surface of the frozen meat is caused by reflectance of light from the well-distributed small ice crystals.

9.3.4.8. Irradiated Meats

Irradiation involves exposing food to electrons, or gamma rays. Irradiation reduces spoilage caused by microbial action. It was found that fresh meat exposed to sterilizing doses of radiation at liquid N_2 temperatures of -300°F (-150℃) was superior in colour, flavour and nutritional value to meat treated at room temperature.

9.3.4.9. Canning of Meat

For safe canning, only meat from healthy animals that have been slaughtered and handled in a sanitary manner should be used. Chilling requires storage in a refrigerator at 40°F or less. Meat that needs to be held for long periods of time prior to canning, should be frozen until it is canned.

9.3.4.10. Packaging

Meat and poultry are packed by either the hot pack or the raw pack method. Meat must be processed at temperatures high enough to kill organisms or bacteria that cause spoilage. The most convenient and economical ways to can meat is precook it. This shrinks the meat. Although salt does not preserve canned meat, it may be added to enhance its flavour. Deteriorative changes like rancidity occur if flesh foods are not

packed airtight and waterproof. The wrappers should not crack or become brittle; at low temperatures, the package should not absorb water, blood or oil.

1. Packing of Frozen Meat:

To maintain frozen meat in as near a perfect condition as possible during storage and distribution of the packaged meat

(a) Dehydration which may be caused by moist water vapour, produced by variations of temperature created within the package, escaping through the walls or ineffective seals of the package.

(b) Greyish white marks that appear on the surface of the meat. It is quite safe to eat such meat, but little dry. After thawing, the meat may be discoloured and unpalatable.

(c) Oxidation due to light, of the meat which is rich in fat.

(d) Flavour or odour loss and absorption of air, or of odours which is possible, if the packaging materials are not impermeable.

9.3.4.11. Cryogenic Freezing of Meat

A rapid freezing method that employs the use of condensed gases is called cryogenic freezing. The low freezing temperature -315°F(-195℃) of liquid nitrogen makes it an excellent freezing medium, or coolant. Nitrous oxide and dry ice are also used in cryogenic freezing. Cryogenic freezing produces a product very close in qualities to unfrozen meat.

Salmonell a bacteria which occur in the intestinal tract of animals as a rule, may spread to the surface of meat/ poultry through processes of handling. Chilled poultry may keep for 1 to 2 days. Hard frozen poultry has to be stored at a holding temperature of 0°, or lower for period of 4 to 6 months. Once deforested, poultry, like other meat, should not be frozen again. Storage temperatures below 0°F are recommended for poultry to retard oxidation, and the resultant rancidity of fat.

9.3.4.12. Chilling: Chilling poultry for storage purpose serves to protect it from spoilage for only a short period. Poultry can be chilled with cold air, or by direct contact with ice or iced water. The cooler the temperature, i.e., the closer it is to freezing, the longer poultry can be stored, and contamination of the egg mass be avoided.

9.3.4.13. Vacuum Packaging

As meat is susceptible to oxygen, vacuum packaging, with low oxygen permeability packaging material, prevents oxidation. However, complete removal of oxygen is not possible since small quantities of oxygen will be trapped in the food. Anaerobic organisms are not affected by the absence of oxygen. Typical materials are used for vacuum packing are polyethylene or polyester film laminates; polyethylene/polyamide film laminates, which are heat sealed. Meat gets spoiled in a chilled atmosphere due to the superficial bacterial slime. The bacteria responsible is Pseudomonas that products a putrid odour. Vacuum packed meat with O_2 inhibits the bacterial growth. However, lactic acid bacteria continue to multiply and therefore, the shelf-life of meat is limited to about 8 to 10 weeks.

Stunning → Killing → Picking → Evisceration
↓ ↓
(Removal of Feathers) (Removal of Offal)
Further Processing ← Holding ← Chilling
↓↓↓

Fresh Frozen Formed
Poultry Poultry Products

During assembly of the live birds (Poultry) and transport to the site of processing, care should be taken that there is minimal bruising.
Chickens are usually slaughtered either by decapitation, or by cutting the jugular vein and carotid artery. Decapitation leads to reduced flow of blood, whereas serving both blood vessels leads to significantly faster bleeding. Studies have shown that use of carbon dioxide to immobilize chickens increase the flow of blood during the first 30 seconds after cutting the blood vessels. Usually, 90 to 180 seconds are allowed for bleeding before the blood carcass can be scalded.

9.3.4.14. Scalding
This is done to facilitate removal of feathers. The birds are immersed in hot water. Four terms are used to designate different scaling conditions: soft, semi, sub and hard. Soft and semi-scalding are used more with broilers and heavy fowl. Sub-scald procedures are used for turkey, with the hard scale method being used mainly for mature birds.

For the soft-scald process, the water temperature is approximately 50℃, and varying times of immersion ranging from 50 to 150 seconds are used, depending on the equipment and the birds being processed. For semi-scald process, the water temperature is slightly higher than that used for soft scald i.e., 53 to 55℃, and the duration is 1 to 2 minutes. For sub scald, a water temperature of 59 -60℃ is used for 45 to 90 seconds.

Use of higher temperatures for scalding has been found to lead to toughening of the outer layers of the meat. In other tests of scalding, it has been found that tenderness of breast meat of chickens was reduced more by longer scalding times, than by higher scalding temperatures. The depth to which the surface layers of breast muscle are affected, and thus the tenderness as well as the appearance of the defeathered carcass, depends upon the time and temperature of scalding. The time scalding to be adjusted in such a manner that either the epidermal layer remains untouched, or is completely removed.

9.3.4.15. Defeathering

This may be done after scalding or ‘dry picking’. For dry picking, the brain is pierced so that the muscles of the feather follicles relax from $\frac{1}{2}$ to $1\frac{1}{2}$ minutes. During this period, the carcass must be defeathered, otherwise the skin tears if this time elapses. In large plants, this is usually done mechanically. The mechanical pickers may remove feathers by rotating rubber fingers which beat on the carcass surface and rub the feathers free of the follicles. Increasing the duration of the beating action or its severity may toughen the meat.

In case of geese or ducks, an additional step is incorporated where the carcass is immersed and dragged through hot wax. The wax is cooled to

become pliable, and it is subsequently stripped. Any feathers that may have escaped the mechanical fingers, especially on the breast or thighs, are then handpicked.

After the carcass is defeathered, the external surface is thoroughly washed, usually with pressurized water jets. Sometimes soft rubber fingers may also be used during washing in order to ensure complete defeathering as well as removal of any other foreign matter from the carcass surface.

The skin/carcass surface is signed by exposure to fames (high temperature) to remove hairs/filoplumes which protrude from the skin surface. Singeing should be extremely well controlled, since at high temperatures the muscle can be cooked and may be irreversibly toughened.

9.3.4.16. Evisceration

Evisceration is usually performed by positioning poultry in an upside down position, hanging the bird by the feet on an eviscerating line. The head, upper esophagus and crop are removed. An incision is made through the abdominal wall and connected with any skin or abdominal wall muscles. All organs from the body cavity are removed, with the intestines, spleen, lungs and reproductive organs being discarded. The carcass is then thoroughly washed both, inside and outside to remove all foreign material and blood clots. The next step is cutting off the hocks and feet.

9.3.4.17. Washing and Chilling

After evisceration, the carcass is washed, both on the outside and the inside. Water is absorbed by the carcass, mostly in the membranes of the body cavity and between the skin and muscle. The degree of water absorption depends upon rigor of washing and cuts made in opening the body. Poultry meat is subsequently chilled by immersion in cold or iced water. In the prechiller, water at a temperature of less than 18.3℃ is agitated. Chilling takes some time, thus during this period, rigor mortismay set in and also be resolved. The bird may then be sold whole, or cut into parts and then sold. Deboning may also be done either by hand or mechanically. Mechanical deboning is done on frames, necks and backs. Mechanical deboning, apparently, has adverse effects on the storage stability of the ground meat because of increased rates of oxidation even during frozen storage. Storage time is a more important factor which affects eating qualities of the product.

Mechanically separated poultry meat can be used as an ingredient for emulsion meat products; it can be mixed with ground beef for preparation of summer sausages.

9.3.5. Control of meat borne pathogens

Effective control of meat borne pathogens and enhancement of meat safety can be achieved by control of latent infections among livestock, animal welfare and humane treatment, application of antimicrobial interventions at the farm, during harvesting, dressing and product processing, improvement in

process food hygiene and potential application of new or novel processing and preservation technologies. Animal stress can damage meat quality and lead to more contamination and increased pathogen shedding. Antimicrobial intervention technologies can be used effectively to improve the microbiological quality of meats. These technologies include reduction of contamination on the raw product, minimization of microbial access to the products, reduction of contamination that has gained access to the product, inactivation of the microbes on the product without cross contamination and prevention and control of the growth of non-inactivated microbes, which have gained access to the meat. An effective pathogen control at pre-harvest, postharvest, processing, storage, distribution, merchandizing, preparation, food-service and consumption of meat include activities employed during pre-harvest or in the field, during post harvest or processing in the plant, at retail and food service and at home. Pre-harvest pathogen control interventions include diet manipulation, use of food additives, antibiotic, bacteriophage therapy, and immunization of the animals, complete exclusion, probiotics and proper animal management practices like pen management, clean feed, clean and chlorinated water, and clean and unstressful transportation. Antimicrobial intervention activities during harvest and post harvesting should be designed to minimize introduction of microbial contaminants and reduce existing contaminant levels through implementation of decontamination and sanitization interventions, processing treatments for partial or complete destruction of contaminants and antimicrobial procedures for inhibition or retardation of microbial growth. Certain inspection regulations should be followed in meat and poultry plants, such as establishment of sanitation standard operating system, operations under the haccp system and performing haccp verifications to meet microbiological standards, establishment of good manufacturing practices (gmp) and good hygiene practices (ghp). Antimicrobial interventions used to control pathogens in further processed meat products include physical hurdles (low and high temperature, non thermal process like irradiation and high pressure and packaging treatments), physiochemical interventions (low ph, reduced water activity, modification of oxidation reduction potential through packaging and application of antimicrobial additives), and biological interventions (microbial competitors, such as lactic acid bacteria and antimicrobial products, such as bacteriocins). Events of the most food borne illness happen due to mishandling of foods in various ways. So, there should be provisions to educate the food handlers and consumers particularly on culinary tips.

9.4 MICROBIOLOGY OF FISH

Fish, especially, begins to deteriorate as soon as it is taken from water, and a good part of available fresh storage life is used up while the fish are in the fishing vessel prior to being loaded for processing. This makes it very necessary that the fish should be stored and packed properly. It is also necessary that the flesh and sea foods be available to the consumer all the year round. Further, such food stuff must be presented to the consumer in such a way that it is convenient to purchase and use. Therefore, storage and processing technology plays a vital role in the post-harvest marketing and consumption of such foods.

9.4.1. Contamination of Fish

The flora of living fish depends on the microbial content of the waters in which they live. Freshwater fish carry freshwater bacteria, which include the members of most genera found in salt water plus species of *Aeromonas, Lactobacillus, Brevibacterium, Alcaligenes, and streptococcus*. The number of bacteria in slime and on the skin of newly caught ocean fish may be as low as 100 and as high as several million per square centimeter and the intestinal fluid may contain from 1,000 to 100 million per milliliter. Gill tissue may harbor 1,000 to 1 million per gram. Washing reduces the surface count.

Oystersand other shellfish that pass large amounts of water through their bodies' pickup soil and water microorganisms in this way, including pathogens if they are present.

Shrimps, crabs, lobsters, and similar seafood have a bacteria-laden slime on their surfaces that probably resembles that of fish. Species of *Bacillus, Micrococcus, Pseudomonas, Acinetobacter, Moraxella, Flavobacterium, Alcaligenes,* and *Proteus* have been found on shrimp.

The number of microorganisms on the skin of fish can be influenced by the method of catching. Fish cakes and fish sticks or similar products represent a large percentage of the consumed seafood in the United States. In the manufacture of fish cakes various other products, including potatoes, spices, and flavorings are mixed with the fish and then the product is molded, coated with batter and bread crumbs, packed, and usually frozen if not used immediately. Many fish-sick items are precooked in hot oil at temperatures of 204 to 232℃. The cooking process is short (2 min or less), and the inside of the product remains frozen. The microbial content of these products would, of course, be quite different from fresh fish as a result of contamination from the ingredients, increased handling, machinery contact, and packaging.

9.4.2. SPOILAGE

Most fish flesh, however, is considered more perishable than meat because of more rapid autolysis by the fish enzymesand because of the less acid reaction of fish flesh that favors microbial growth.Also, many of the unsaturated fish oils seem to be more susceptible to oxidative deterioration than are most animal fats. Rigor mortis is hastened by struggling of the

fish, lack of oxygen, and warm temperature and is delayed by a low PH and adequate cooling of the fish. The PH of the fish flesh has an important influence on its perishability, not only because of its effect on rigor mortis but also because of its influence on the growth of bacteria. Lowering of the PH of the fish flesh results from the conversion of muscle glycogen to lactic acid.

9.4.2.1 Factors Influencing Kindand Rate of Spoilage

The kind and rate of spoilage of fish vary with a number of factors:

1. The kind of fish. The various kinds of fish differ considerably in their perishability. Thus some flat fish spoil more readily, than round fish because they pass through rigor mortis more rapidly, but a flat fish like the halibut keeps longer because of the low PH (5.5) of its flesh. Fishes high in trimethylamine oxide soon yield appreciable amounts of the "stale-fishy" trimethylamine.

2. The condition of the fish when caught. Fish that are exhausted as the result struggling, lack of oxygen, and excessive handling spoil more rapidly than those brought in with less ado, probably because of the exhaustion of glycogen and hence smaller drop in PH of the flesh. "Feedy" fish, i.e., those full of food when caught, are more perishable than those with an empty intestinal tract.

3. The kind and extent of contamination of the fish flesh with bacteria. These may come from mud, water, handlers, and the exterior slime and intestinal content of the fish and are supposed to enter the gills of the fish, from which they pass through the vascular system and thus invade the flesh, or to penetrate the intestinal tract and thus enter the body cavity. This contamination may take place in the net (mud), in the fishing boat, on the docks, or, later, in the plants. Fish in the round, i.e., not gutted, have not had the flesh contaminated with intestinal organisms, but it may become odorous because of decay of food in the gut and diffusion of decomposition products into the flesh. This process is hastened by the digestive enzymes attacking and perforating the gut wall and the belly wall and viscera, which in themselves have a high rate of autolysis. Any damage to skin or mucous membranes will harm the keeping quality of the product.

4. Temperature. Chilling the fish is the most commonly used method for preventing or delaying bacterial growth and hence spoilage until the fish is used or is otherwise processed. The cooling should be as rapidly 0 to -1 C, and this low temperature should be maintained. Prompt and rapid freezing of the fish is still more effective in its preservation.

5. Use of an antibiotic ice or dip.

9.4.2.2 Evidences of Spoilage

Since the change is gradual from a fresh condition to staleness and then to inedibility, it is difficult to determine or agree on the first appearance of spoilage. A chemical test for trimethylamine is backed by most workers for use on saltwater fish, although some support other methods, such as an estimate of volatile acids or volatile bases or a test for PH, hydrogen sulfide, ammonia, etc. bacteriological tests are too show to be useful.

Meanwhile a sequence of odors is evolved; first the normal, fresh, seaweedy odor, then a sickly sweet one, then a stale-fishy odor due to trimethylamine followed by ammoniacal and final putrid odors due to hydrogen sulfide, indole, and other malodorous compounds. Fatty fish also may show rancid odors. Cooking will bring out the odors more strongly.

9.4.2.3 Bacteria Causing Spoilage

The bacteria most often involved in the spoilage of fish are part of the natural flora of the external slime of fishes and their intestinal contents. The predominant kinds of bacteria causing spoilage vary with the temperatures at which the fish are held, but at the chilling temperatures usually employed, species of *Pseudomonas* are most likely to predominate, with *Acinetobacter*, *Moraxella*, and *Flavobacterium* species next in order of importance. Appearing less often, and then at higher temperatures, are bacteria of the genera *Micrococcus* and *Bacillus*. Most of these would grow only at ordinary atmospheric temperatures and probably would do little at chilling temperatures.

Normally pseudomonads increase in numbers on chilled fish during holding, achromobacters* decrease, and flavobacteria increase temporarily and then decrease. The bacteria grow first on the surfaces and later penetrate the flesh. A musty and muddy odor and taste of fish has been attributed to the growth of *Streptomyces* species in the mud at the bottom of the body of water and the absorption of the flavor by the fish.

9.4.2.4 Spoilage of Special kinds of Fish and Seafoods

The previous discussion has been limited for the most part to the spoilage of fish preserved by chilling. Salt fish are spoiled by salt-tolerant or halophilic bacteria of the genera *Serratia*, *Micrococcus*, *Bacillus*, *Alcaligenes*, *Pseudomonas*, and others, which often cause discolorations, a red color being common. Mold are the chief spoilage organisms on smoked fish. Marinated (sour pickled) fish should present no spoilage problems unless the acid content is low enough to permit growth of lactic acid bacteria or the entrance of air permits mold growth. Japanese fish sausage is subject to saouring caused by volatile acid production by bacilli or to putrefaction, despite the addition of nitrite and permitted preservatives.

In general, shellfish are subject to types of microbial spoilage similar to those for fish. Crabmeat is deteriorated by *Pseudomonas*, *Acinetobacter*, and *Moraxella* at chilling temperature and mainly by *Proteus* at higher temperatures. Species of *Pseudomonas*, *Alcaligenes*, *Flavobacterium*, and *Bacillus* have been incriminated in the spoilage for row lobsters. The levels in these products fluctuate with seasonal temperatures changes.

Oysters remain in good condition as long as they are kept alive in the shell at chilling temperature, but they decompose rapidly when they are dead, as in shucked oysters. Oysters are not only high in protein but also contain sugars, which result from the hydrolysis of glycogen. At temperatures near freezing, *Pseudomonas*, *Acinetobacter*, and *Moraxella* species are the most important spoilage bacteria, but Flavobacterium and Micrococcus* species also may grow. The spoilage is termed “souring” although the changes are chiefly proteolytic. At higher temperatures the souring may be result of the fermentation of the sugars by coliform bacteria, streptococci, lactobacilli, and yeast to produce acids and a sour odor. Early growth of *Serratia*, *Pseudomonas*, *Proteus*, and Clostridium may take place. An uncommon type of spoilage by an asporogenous yeast causes pink oysters.

9.4.3 PRESERVATION

Of all the flesh foods, fish is the most susceptible to autolysis, oxidation and hydrolysis of fats, and microbial spoilage. Its preservation therefore involves prompt treatment by preservative methods. When fish are gathered far from the processing plant preservative methods must be applied even on the fishing boat. Evisceration should be done promptly to stop active digestive enzymes in the gut. Advantages gained by gutting may be offset by a possible delay in rapid cooling of the fish.

Rigor mortis is especially important in the preservation of fish, for it retards postmortem autolysis and bacterial decomposition. Therefore, any procedure that lengthens rigor mortis lengthens keeping time. The ultimate PH of the fish after death is related to the amount of glycogen available at death. The more glycogen present, the lower the PH. The less muscular activity before death, the higher the level of glycogen, or the lower the ultimate PH. Reducing the holding temperature will lengthen the period.

Aseptic methods to reduce the contamination of seafood are difficult to apply, but some of the gross contamination before processing can be avoided by general cleaning and sanitization of boats, decks, holds, bins, or other containers and processing equipment in the plant and by the use of ice of good bacteriological quality. The removal of organisms is difficult, but the fact that most of the contamination is on the outer surface of the fish and other seafood permits the removal of many of the microorganisms by washing off slime and dirt.

9.4.3.1 Preservation and storage of fish

Various techniques are used for the storage and preservation of fish and other sea foods.

1. Chilling: Chilling is one of the methods used for temporary preservation of fish. However, even at low temperature are used for refrigeration, enzymes that cause spoilage of the fish are active. Also, fish oil becomes oxidised at low temperatures above freezing point are vulnerable to rapid deterioration. Although temporary refrigeration/chilling does keep spoilage

at a minimum, the use of antibiotics and other preservatives in the crushed ice can help to retard bacterial growth.

2. Smoking: Smoking fish involves the following processes:

- **Splitting and Cleaning:** The fish is split, and the gut, gills and kidney are removed since their presence would hasten the process of deterioration, and spoil otherwise good fish.
- **Salting:** The cleaned fish is then soaked in brine. Duration of treatment with brine depends on the strength of the brine solution, and the size and condition of the fish. For optimum results, the brine is stored at the temperature of 52 to 55°C, and is changed at least once a day.
- **Hanging:** The salted-fish is hung in the kiln on a rack for dripping. The protein, which has dissolved in the salt to form a sticky solution on the fish surface, gives the skin the glossy appearance which is one of the commercial criteria of quality.
- **Smoking:** Smoking is two types Hot or Cold. During hot smoking, the fish gets cooked. Smoking is done in kilns. Sawdust is smouldered at the bottom of the fish is hung above it and may burst into flames and cook the lower fish, which might fall into the fire and, thus lead to wastage. Once the process of smoking is complete, the fish is cooled. During the cooking process it loses weight.

Through the years, various ways of pyrolyzing wood to produce smoke-flavour compounds have been developed. When using smoke to process fish, it is essential that environment pollution is minimised. Six major techniques are used. In all of them the major steps are used for smoking are as follows:

Wood pyrolysis in a separate chamber
↓
Smoke generator
↓
Channelisation of the smoke into chamber containing food items

In many modern units, photoelectronic control is used to produce efficiently, smoke which is uniform composition, to obtain maximum smoke colour and flavor, as well as minimum smoke pollution. The techniques used for smoking are briefly discussed below:

i. Smoldering:

- The wood is burnt usually in the form of sawdust.
- Allowed to smolder by the action of heating oil or gas flame.
- Smoke is pushed into the smoking chamber for interaction with the food. The amount of tar and other solid particles is controlled by the distance of smoking unit from the smoldering unit.
- Increase the distance between the two units helps to increase the settling down the tar and lower smoldering temperatures can be effected by controlling the amount of air.
- If wood with a moisture content of approximately 30% is used, the temperature can be reduced by 100 to 300° as compared to temperature if dry wood were used.

ii. Friction:

- Intact wood blocks are pressed against a rotating metal friction wheel, producing heat.
- Air is permitted to enter through Centre of friction wheel to cool the smoke which is produced as a result of wood pyrolysis caused by heat produced by the friction between the metal and wood.
- Smoke generation may be continuous or discontinuous.
- In continuous type, the smoke temperature may be 140 to 160°C. In discontinuous type, operations are usually of a duration of 10 seconds, with rest intervals of several minutes between the operations.

iii. Wet or Condensate Smoke:

- Sawdust is blended with superheated steam and varying amounts of heated air, and is pyrolysed.
- The smoke temperature is about 80°Cand smoke is moist due to the condensed moisture from the steam.
- The advantages of this technique the treatment time is shorter than in other methods and the smoke yield is improved.

iv. Fluidization:

- Air is heated (300 to 400°C) under high velocity electrically after it is mixed with sawdust.
- Turbulence in the air leads to suspension of the sawdust particles.
- Pyrolysis occurs about 350°C in 10 seconds due to higher air temperatures.

v. Two Stage Modified Fluidization:

- In first stage, Pyrolysis takes place by the action of N_2 or CO_2 at 300-400°C.
- In second stage, the reactants of stage I are mixed with O_2, or air, and heated to about 200°C after which further pyrolysis is carried out.
- Oxidation, condensation and polymerization reactions are promoted in second stage.

vi. Carbonization:

This technique requires specialized equipment.

- Sawdust is pressed together in a tabular casing by means of special screw.
- At the end of compressive device, is a variable temperature electrical heating element. Since compressed sawdust lacks air,smoke is produced during carbonization.

3. HOT versus COLD Smoking

Actual smoke temperatures vary quite widely according to the method used for generating the smoke, as well as ambient temperature surrounding the food item being smoked. When the ambient temperature surrounding the food item being smoked. When the ambient temperature is high, the food undergoes some amount of cooking and absorbs, and reacts with the components in the smoke.

For cold smoking, the temperature is usually 15 to 25°C, and for hot smoking the temperature are usually in the range of 55 to 80°C. Foods that

are smoked typically by cold smoking are raw ham and bacon, whereas cooked ham and frankfurters are usually treated with hot smoke.

- Hot smoking may be done within several hours
- Cold smoking may take upto several weeks, for appropriate colour and flavor is generated.

Moist smoking is also used for dry sausage or salami. For this, the chamber temperature should be about 24 to 48°C, and the relative humidity should be greater than 30%

Dark smoking is used to give the food a strong smoky character by using dense smoke to blacken the food surface. However, such foods are quite high in polycyclic aromatic hydrocarbons and their safety from view of health is questionable.

Smoking imparts a typical flavor to the food products. The important flavor compounds in wood smoke are: phenolic compounds, furans, carbonlys, lactones and pyrazines.

4. Effects of Smoking on Nutritional Quality: One important consideration is the stability on the essential amino acids. Among these, lysine poses the major concern as it limiting in the most foods, besides being very reactive. Extent of loss of available lysine is influenced by smoking time, and temperature, storage time, and water activity during storage.

Phenolic and neutral fractions of smoke apparently contain compounds that are primarily responsible for loss of available lysine. Smoking also causes significant losses of sulfur containing amino acids.

There are some nutritional benefits that may also be achieved by smoking. It has been reported that smoking improves protein digestibility, probably via protein hydrolysis. However, losses of some B-vitamins has also been reported. Smoke also has some anti-oxidant properties and from a practical standpoint, it may help in preventing the onset of rancidity of the lipids.

5. Curing

Fish may be cured in one of several ways:

(a) Heavy and hard Cure: Here the fish is headed, split along the belly and the backbone is removed. The tail portion is retained, since it is imparts rigidity to the split fish. Green cure is said to be lying in wet stock. At frequent intervals, the fish are restacked with the top layers going to the bottom and the bottom layers over the top produce an even cure. The moisture content of the final product is 10 to 30%, and the salt content is approximately 25 to 35%.

(b) Gaspe or Light Cure: The gilled, headed and split fish is placed in a tub with split side uppermost. Layers of salt are added by alternating salt with the layers of fish. Approximately, 7.9 lbs of salt is used for every 100 lbs of fish. The fish is subsequently, stacked for 5 to 6 hours to press out some liquid, and then dried either by sundrying or in mechanical driers.

(c) Pickle curing: This process is used mainly for fatty fish, such as herring. When the hirring are landed, they are sprinkled with salt (14 lbs for every can) to prevent deterioration during transport and while awaiting further processing. They are then packed in barrels, with alternating layers of fish called Sea Stick. After 10 days the lid is removed. More fish of the same cure is added to fill the barrel and again tightly packed. Blood pickle is again run in to fill up spaces between the fish. The barrel is now ready for storage.

6. Freezing

Freezing extends the period of storage and is effective in keeping the fish in a condition approximately similar to that of fresh fish. The three most important methods of freezing fish are:

* By direct contact between the fish and a refrigerated metal plate.
* By blowing a continuous stream of refrigerated air over the product
* By immersing the fish in a low temperature liquid

a. Air Blast Freezing: Cold air is passed over the fish in one of two ways. In one method, the product moves through the freezer during the freezing process. In second method, product remains stationary.
Blast Freezers: Accommodate all shapes and sizes of products and are particularly suitable for freezing large single fish and blocks of packs of irregular shapes.

b. Plate Freezers: Fish are frozen between pairs of metal plates through the refrigerant passes. Packaging both insulates the product and the hinders close contact between the products and plate. The low spots are moved farther away from the plate. Horizontal as well as vertical plate freezers are available.

c. Immersion Freezers: The disadvantage of freezing fish in air can be lessened or a avoided by freezing them in liquids which have high heat capacity and conductivity.

Refrigerated brine made a solution of common salt water is suitable. Fish immersed directly in the brine can be frozen very quickly, since excellent contact is made between the fish and the refrigerant.

d. Hybrid Freezers: various hybrids of air blast and plate freezing plants can be used; like fish can be frozen in trays laid upon refrigerated shelves over which cold air is blown. Large fish may be frozen by sharp freeze- a comparatively slow freeze. Smaller fish are frozen very quickly. The quick frozen fish tend to be more attractiveand as such have more consumer acceptability.

Freezing also kills some microorganisms and deactivates others, Denaturation of considerable amount of proteins occurs during freezing due to loss of moisture resulting in an increased salt concentration, which causes the denaturation.

e. Dessication: Transfer of moisture from the surface of fish to the cold metal surface on which the fish rest during freezing, occurs. It may also be caused by air currents. The air close to the fish in the storage room is warmer than the refrigeration pipes, and is able to absorb large amount of moisture from the fish.

Another less controllable form of dessication is caused by evaporation of water from the fish flesh to the air, via interstices within the muscle fibres. This evaporation may be reduced by covering the fish with a dilute brine that fills the interstices.

Frozen fish undergo undesirable oxidation changes. In general fatty fish react with O_2 and become rancid much more quickly than lean fish.

f. Reducing Dehydration: The temperature of the product must be kept as steady as possible since fluctuations increase the amount of damage to the fish. Generally, a rise in temperature increases the extent of dehydration. Whenever there is a difference in the temperature between the product and some other part of the store, there is a difference in water-vapour pressure. Thus, water vapour migrates from the product to any colder surface. The greater the temperature difference, the faster the water will be transferred. As a result, the fish will dry out; and this condition is called freezer burn.

g. Insulation: At temperatures at which fish is stored, or when only solid microcellular insulating material are used, eg., granulated slab, expended ebonite, foamed plastic slab, moisture will always tend to pass from the warm air outside a cold store wall to the colder air inside. This moisture freezes on the insulation and it becomes gradually saturated with the water and insulation value falls rapidly until it is completely destroyed.

h. Temperature control: The temperature in small cold stores is usually controlled by a thermostat that starts and stops the compressor. In large installations where several freezers may be run by the same machine, the thermostat usually controls the flow of the refrigerant to the cooling coils.

i. Packaging of the frozen fish: For packaging raw fish portions, polyethylene films are used as perforated bags or wrapping. In frozen fish, the high salt content can corrode the metal in contact with the produce and therefore, stainless steel equipment is essential. PVDC copolymer is now being used.

j. Transport of Frozen Fish: Frozen fish delivered to a continuous outlet where it is going to be used within a few hours of arrival can be partially thawed during the journey. But fish transferred from one cold storage to another should not warm up en route; therefore, it should be carried in insulatedcontainers.

k. Thawing of Frozen Fish:

(a) In water: Fish thawed in water are satisfactory, more so when the thawing is carried out under controlled conditions. But fillets get spoiledand loss their flavourif they are water logged or immersed in water

for too long. The water used for thawing should be changed, and filtering of fish smile and blood is necessary.

(b) In air: Still air or moist air can be used for thawing fish. Industrial air blast thawing can be done by use of fuel. A heat exchanger in the air stream and a water sprayer to humidify the air can be filled in. The air flowing can be at right angles to the direction along the conveyor or parallel to the direction of the fish that are to be thawed.

7. Electrical Methods

(i) Electrical resistance thawing: This consist of passing a current directly to a block of fish. When the current passes through any material it heats up the material. For uniform thawing, the material should be uniform throughout.

(ii) Dielectric thawing: Here blocks of frozen fish are carved on an endless rubber conveyor belt which passes on one or more pairs of electrodes one above and one below the conveyor. An AC voltage of high frequency is applied. The energy is produced in the fish in the form of heat. The fish should not touch the electrodes.

8. Canning Operations

In canning fish, the principles are as follows:

(a) Heat is used to avert spoilage by microbial destruction;
(b) Salt is used as the main preservative, along with sugar or oil or smoke constituents, and
(c) Acid is a main ingredient as well.
The most important thermos-resistant spore forming organisms are **Clostridium sporogenes, Clostridumputrefaciens**and **Bacillus sp**. It is not possible to predict which species of heat resistant bacteria are presented in a food, hence, it is safest to carry out processing so that the most dangerous spore-former, i.e., **Clostridium botulinum**is destroyed.
The basic operations in canning are as under:

(a) Handling and storage of empty cans

(b) Cleaning of empty cans

(c) Product preparation

(d) Filling

(e) Closing of cans

(f) Processing

(g) Cooling and

(h) Handling and storage of filled cans

Treatment of fish before canning: The following operations need be carried out before the canning of fish:

i. Nobbing: The head and gut are removed in large fish. This procedure is called nobbing. Dressing of fish is done by removal of scales for herring type fish in rotating mesh cylinders. For small fish as well, the head and intestines are removed. Removal of backbone shortens the time that is required for precooking mackerel.

ii. Washing and Descaling: Nobbing releases blood which must be removed because it causes staining in the processed fish. In this slim is also removed.

iii. Brining: This fish are immersed in a concentrated solution of common salt. Salt is absorbed by the flesh and the imparts a desired flavor to the finished product.

iv. Handling and Storage of Empty Cans: Tin plate containers do not have unlimited resistance to physical abuse, nor can they withstand indefinitely conditions which could promote corrosion. Cans should be transported in a manner that will avoid damage to the tins, excessive cleaning or rupture of soldered caps. In coastal areas, even small amounts of sea salt promote corrosion.

v. Cleaning Empty Cans: Washing should be done by sprays of hot water with cans in the inverted position with jets of water sprayed over them to ensure proper cleaning.

9. Product Preparation

(a) Filling: Cans should be filled uniformly and with the proper amount of contents. Paper filling serves to expel undesirable gases, especially oxygen, 160and cooling. Cans which have stains (internally or outside) should not be used to avoid corrosion by oxygen. The magnitude of the vaccum produced is controlled by choosing suitable filling temperature and head space dimensions.

(b) Closing: Canning is based on heating the sealed containers until the contents are commercially sterile. Therefore, it is essential that the sealing operations, also called closing or double sealing, be such that recontamination of the food by microorganisms is precluded during subsequent cooling, handling and storage of cans.

(c) Processing: Thermal processing of cans is by application of heat at a specified temperature for specified time. This is to produce a commercially saleable product. Processing is also essential for cooking the food material upto a point where minimum further preparation is required as far as the consumer is concerned.

Thermal treatment of the entire can contents must be at least equivalent to 4 minutes at 120℃ or 10 minutes at 115℃ to kill most heat resistant strains even in large numbers. Thermal value is often related to ‘F-value’, i.e., the time in the minutes for which the product should be maintained at 121℃. The required F-value is difficult to establish. Too long a heating leads to the development of a brownish colour due to the Malliard reaction.

(d) Cooling: Sealed cans have to be cooled after processing. Cooling halts the deterioration that would occur in the product due to over cooking. For example, overcooking leads to excessive softening of the food or objectionable changes in flavor and colour. Cooling is done with cool water passed through retortion by which the cans are processed, or by passing the cans under a shower of cold water.

(e) Handling and Storage of Filled Cans: Rough handling and contaminated runways can lead to spoilage. Storage of cans at excessively high temperature or under conditions favourable to corrosion may ruin an otherwise satisfactory pack.

In tropical climates and especially in locations near salt water, the protection that is provided by conventional tin coating may be inadequate to prevent corrosion on the outside of the cans placed in storage.

10. Fish Meal and Fish Oils

A considerable proportion of the total fish catch is not sealable for human consumption. Some fish will at times fail to find a market, and some may be discarded because of hygenic considerations. Much of the fish bought for human consumption is processed in some way before it reaches the retail stage, and this results in discarding heads, bone, fins, etc. It constitutes a valuable ingredient of the diets of farm animals, particularly young pigs and poultry.

The press liquor is fixed from coarse pieces of solid material by a suitable mist or by centrifuging solid recovered from press liquor. The oil and water separation is done by a high speed centrifuge from where they are separately collected and stored. The pressed cake is fish meal, which is used for fodder. First flow is applied for fish meal prepared for human consumption. Such processes are usually intended for use in areas where poverty causes defects in good quality protein. This fish flow is called fish protein concentrate.

"Whole fish protein concentrate is derived from whole, wholesome hake-like species of fish consisting of essentially dried fish processed from the whole fish without removal of head, fins, tail, viscera or intestinal contents. It is prepared by solvent extraction of fat and moisture with $C_2H_4Cl_2$, followed by isopropyl alchol. Bone is partially removed. It meets the following specifications:

Protein content (min)	75 percent
Protein quality (min)	100
Moisture (max)	10 percent
Fat (max)	0.5 percent
Residual solvents (max) Isopropyl alchol	250 ppm

$C_2H_4Cl_2$ 5 ppm

It should be free of E.coli and pathogenic organisms including Salmonella, and have a maximum total bacterial plate count of 1000 per gm of material. The specifications for fish protein concentrate are as follows:

Content	Type A	Type B	Type C
		Minimum %	
Protein	67	65	60
Pepsin digestibility	92	92	92
Avaliable lysine	6.5	6.5	6.5
		Maximum %	
Moisture	10	10	10
Fat	0.75	3	10
Chloride	1.5	1.5	2
Silica	0.5	0.5	0.5

Fish may be dehydrated for most kinds of fish foods, but this processing technique has been replaced by either canning or freezing.

9.5 Suggested Readings

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UNIT X – SPOILAGE OF CANNED FOODS

10.1. Introduction
10.2. Objectives
10.3. Spoilage foods
10.4. Canned foods
10.4 High-pressure processing: pascalization
10.5 Low temperature storage: chilling and freezing
10.6 Chemical preservatives
10.7 Organic acids and esters
10.8 Natural food preservatives
10.9 Control of water activity
10.10 Compartmentalization
10.11 Unit- end- exercises
10.12 Suggested readings

10.1. INTRODUCTION

Canned foods are significant component in the diet of most individuals in developed countries, offering food in a convenient form with year-round availability. The canning process relies on heat treatment for the destruction of microorganisms and preservation of the food, which is then generally considered to have an indefinite microbiological shelf-life providing that pack integrity is maintained. The extent of the thermal processing, in terms of both temperature and duration of the treatment, is dependent upon the chemical and physical composition of the product. Both physical and chemical changes occur during processing and, to a lesser extent, during storage, and it is these that determine the product quality in terms of its sensory properties and nutrient content. These changes, which can be either desirable or undesirable, are influenced by the time and temperature of the process, the composition and properties of the food, the canning medium, and the conditions of storage.

10.2. OBJECTIVES

After going through this unit, you should be able to:

- Discuss about canned foods and types
- Contamination and spoilage of canned foods
- Preservation and control of canned food spoilage

10.3. SPOILAGE OF CANNED FOODS

If a canned food contains viable microorganisms capable of growing in the product at ambient temperature, then it will spoil. Organisms may be present as a result of an inadequate heat process, under-processing, or of post process contamination through container leakage. Spoilage by a single spore former is often diagnostic of under-processing since rarely would such a failure be so severe that vegetative organisms would survive.

The spore-forming anaerobes *Clostridium* can be either predominantly proteolytic or saccharolytic but both activities are normally accompanied by gas production causing the can to swell. Cans sometimes swell as a result of chemical action. Defects in the protective lacquer on the inside of the can may allow the contents to attack the metal releasing hydrogen. These hydrogen swells can often be distinguished from microbiological spoilage since the appearance of swelling occurs after long periods of storage and the rate at which the can swells is usually very slow.

In cases where microbial growth occurs without gas production, spoilage will only be apparent once the pack has been opened. *Bacillus species*, with the exceptions of *B. macerans* and *B. polymyxa*, usually break down carbohydrates to produce acid but no gas giving a type of spoilage known as a 'flat sour'.

The heat process, a product receives is determined largely by its acidity. The more acidic a product is, the milder the heat process applied. A product's acidity also determines the type of spoilage that may result from under-processing since it can prevent the growth of some spoilage organisms. At normal ambient temperatures only mesophilic species will grow. Typical examples would be *C. botulinum*, *C. sporogenes*, and *B. subtilis* in low acid products and *C. butyricum* and *C. pasteurianum* in products with a PH below 4.5.

Cans are cooled rapidly after processing to prevent spoilage by thermophiles. Thermophilic spores are more likely to survive the normal heat process but would not normally pose a problem. If however a large assemblage of cans is allowed to cool down naturally after retorting, the process will be slow and the cans will spend some time passing through the thermophilic growth range. Under these conditions surviving thermophilic spores may be able to germinate and grow, spoiling the product before it cools.

Thermophilic organisms commonly associated with spoilage of low acid canned foods are the saccharolytic organism *C. thermosaccharolyticum*, *B. stearothermophilus* and *Desulfotomaculum nigrificans*. The last of these causes a type of spoilage known as 'sulphur stinker'. It produces hydrogen sulphide which does not usually distant the can but does give the product on objectionable smell and reacts with iron from the can to cause blackening.

10.3.1 ASEPTIC PACKAGING

In such processing the food is heat processed before it is packed and then sealed into sterilized containers in a sterile environment. This allows more rapid heating of the product, the use of higher temperatures than those employed in canning, and processing times of seconds rather than minutes. This means that higher temperatures will increase the microbial death rate more than they increase the loss of food quality associated with thermal reactions.

Initially aseptic packaging was confined to liquid products such as milk, fruit juices and some soups which would heat up very quickly due to convective heat transfer. During this process the use of ohmic heating is employed in which a food stream is passed down a tube which contains a series of electrodes. An alternating voltage is applied across the electrodes and the food's resistance causes it to heat up rapidly. Most of the energy supplied is transformed into heat.

A common packing system used in conjunction with UHT processing is a from/fill/seal operation in which the container is formed in the packaging machine from a reel of plastic or laminate material, although some systems use performed containers. Packaging is generally refractory to microbial growth and the level of contamination on it is usually very low. Nevertheless to obtain commercial sterility it is given a bactericidal treatment, usually with hydrogen peroxide, sometimes coupled with UV irradiation.

IRRADIATION

As far as food microbiology is concerned, only three areas of the electromagnetic spectrum are related, microwaves, the UV region and gamma rays.

Microwave Radiation

Microwaves act indirectly on microorganisms through the generation of heat. Microwaves have been used to defrost frozen blocks of meat prior to their processing into their products such as burgers and pies thus reducing wear and taer on machinery. There has also been a limited application of microwaves in the blanching of fruits and vegetables and in the pasteurization of soft bakery goods and moist pasta to destroy yeasts and moulds. Microwaves have also been used to pasteurize high-acid foods, such as fruits in syrup, intended for distribution at ambient temperature. These are packed before processing and have an indefinite microbiological shelf life because of the heat process and their low PH.

10.3.2 FOOD-RELATED USES OF MICROWAVES

Microwave heating of food is useful in institutional foodservice, in the home, and also in the food industry for processing. Heavy-duty commercial units are often installed in in foodservice establishment. They have higher output capabilities and are designed to withstand rough treatment. Although microwave ovens are widely used in the foodservice industry, they are currently employed primarily for reheating. For example, hospital foodservice use of microwaves is often as part of a system in which individual plates of chilled menu items are reheated, one meal at one time, just prior to service to the patient. Defrosting and primary cooking now consume a relatively small proportion of total use time, but there is great potential for expansion, particularly in the area of primary cooking.

Microwave energy applications in the food industry are many, with equipment especially designed for each type of product. These uses include thawing or tempering frozen foods; drying such products as past, potato chips, vegetable concentrates and fruit, yeast, mushrooms, and fish protein; roasting nuts and coffee; baking, bread, pizza, cake, and pastry products, often in combination with conventional baking; and pasteurizing and sterilizing yogurt, meat products, poultry, eggs, milk products, and other foods. Time saving, as well as energy conservation, is important consideration in food processing.

10.3.3 ACTION OF MICROWAVES IN HEATING

- Microwaves are high-frequency electromagnetic waves, falling between infrared/visible light waves and radio waves in frequency. They are generated in a vacuum tube called a magnetron that converts alternating electric current from a house hold circuit into electromagnetic energy radiation. A stirrer blade in the top of the oven helps to distribute the waves produced.
- Metals reflect the short, straight microwaves. The metal walls of a microwave oven and reflect and thus contain the microwaves within the oven cavity. Microwaves reach the food that is to be cooked both directly from the magnetron unit and indirectly by reflection from the metal walls.
- The Federal communications commission has assigned certain frequencies for microwave cooking to avoid interference with communication systems that operate in closely associated frequencies. These assigned frequencies are 915 and 2450 megahertz (million cycles per second). The higher the frequency, the shorter is the wavelength and the shallower is the depth of penetration of the waves into the food being cooked. At a frequency of 2450 megahertz, the wavelength is approximately 4.8 inches, whereas at a frequency of 915 megahertz, the wavelength is about 13.5 inches. The shorter wavelengths produce more uniform heating and better results for small items being cooked. Microwave cooking may be satisfactory accomplished at either frequency, however. Ovens designed for home usually operate at 2450 megahertz.
- Some manufacturers have combined a conventional electric oven with a microwave oven in the same compartment, whereas others have provided conventional electric oven combination is also available.
- Variable cooking power outputs are made possible in a microwave oven by changing the design of the magnetron tube. Household ovens usually have an output capability up to 600 or 700 watts, whereas commercial/foodservice units may have wattage as high as 1000 to 2000. The design assumption for these heavy-duty units is for use hundreds of times per day. The higher the wattage, the more microwaves produced, and the faster the cooking.
- High-speed cooking can be slowed down in most microwave ovens presently manufactured, allowing cooking on various medium and low speeds. This has increased the adaptability of the oven for many different products. Automatic features are also often

included. For example, some ovens automatically determine the cooking time and power level when the weight of a roast of meat or poultry is entered into the program. Some sensor programs can automatically determine doneness and then turn off the oven, or, alternatively, the product can be cooked and then held warm for a period. In addition, defrost cycles are often automatic.

- The U.S. Food and Drug Administration (FDA) enforce a radiation safety standard for the manufacture of microwave ovens. The standard limits the amount of microwaves that can leak from an oven throughout its lifetime. Microwave ovens are as safe as other cooking appliances. The amount of exposure to radiation is limited to 1/10,000th of the amount known to cause any harm to humans.

10.3.4 How Do Microwaves Work in Cooking Food

- Basically, they are absorbed directly by the food in the oven. The energy entering the food causes electrically polarized molecules in the food, including water, to reserve their positions to realign themselves to the rapidly changing electromagnetic field. The rapid rotation of the molecules produced friction that creates heat within the food, thereby cooking it. The microwaves generally penetrate about 1 to 2 inches into the food, the depth varying with the frequency of the microwaves and the composition of the food. Further distribution of the heat, particularly toward the center of a relatively large mass of food, occurs by conduction, as it does in conventional heating.
- Both microwave heating and the radiant heating used in conventional broiling and breaking produce heat by increasing the motion of the molecules as energy is absorbed. Microwave do not, as is sometimes supposed, cook from the *inside out*. Microwave cooking is faster, however, because microwaves penetrate farther into than does the infrared radiation used depths in the food. As the air inside the oven is cool, the surface of the food does not become hot enough to develop a brown, dry, and crusty surface as does that of conventionally baked products.

The consumption of a food affects the rapidity of heating. Fats and sugars have low specific heats compared with water; therefore, foods high in fat or sugar heat more rapidly than food high in water. Foods that are less dense also heat more rapidly than high-density foods when similar weights of these products are heated. Dense foods limit the depth of penetration of the microwaves. For example, a dense brownie batter heats more slowly than a light, porous cake.

10.3.4.1 Advantages

- One of the great advantages of using a microwave oven is the speed with which cooking may be accomplished – two to ten times faster than conventional methods. The actual time required for cooking depends on the volume and type of food being cooked.

Microwave ovens are not generally designed for quantity cookery, and the time of cooking must be lengthened as the quantity of the food cooked is increased. One potato, for example, may cook in 4 to 6 minutes in microwave oven, whereas four potatoes require 16 to 19 minutes to cook.

- The microwave oven has a real advantage in the saving of energy when compared with conventional ovens, particularly for cooking up to about six servings at one time. When larger amounts of food are cooked, the energy/cost comparisons may change. On tests with a variety of food types and menus cooked in a microwave oven and on the surface units and oven of a conventional electric range, it was shown that the microwave oven consumed less energy in 100 of 127 tests. In other comparisons, energy use for surface cooking and microwave cooking was comparable, whereas broiling and baking used more energy. In cooking pork sausage links, the microwave oven had the lowest energy requirement, followed by the convection oven, with the still-air oven requiring the most energy. An additional saving of energy from microwave use comes from the lesser amount of dishwashing that is generally required. Containers used for cooking are usually suitable for serving.
- Still another advantage of microwave cooking is that the oven walls and surrounding air do not become hot. Only the food is heated. If the cooking period is sufficiently long, some heat is conducted to the container that holds the food; however, the likelihood of receiving severe burns from the handling of cooked food is decreasing.

10.3.4.2 Limitations

- As noted earlier, foods cooked in short periods in a microwave oven do not become brown on the surface, as do many foods that are baked on roasted in a conventional oven or cooked in a skillet. With many baked products particularly, a browned surface is very desirable. A loaf of bread without a crisp, golden-brown crust does not have the same appeal as one that possesses these characteristics.
- To overcome to some degree the problems created by lack of browning, and special browning dish may be used to sear chops, meat patties, steaks and similar products. A special coating on the bottom of the dish absorbs the microwave energy and becomes very hot (450° to 550°F). The dish is preheated according to the manufacturer’s directions, the food is added and cooking is continued according to the recipe being used.
- Foods that need long cooking periods at simmering temperatures to tenderize or to rehydrate are not satisfactorily prepared in the microwave oven. Some flavors do not have an opportunity to develop as well in a short cooking period.
- It is relatively easy to overcook foods in the microwave oven because heating is rapid. Caution must be exercised to void the dehydrating effects that may result from only a few seconds, in some cases, of overheating.

- Problems may result from heating several menu items on a single plate because of variations in the rate of heating each item resulting from differences in the composition and density. When individual portions of meat loaf (beef), mashed potatoes, and green beans were heated in a microwave oven, simulating procedures used in cook/chill foodservice systems, a wide range up to 83°F (46°C) of endpoint temperatures was observed.

10.3.5. Utensils used in Cooking

Microwaving requires the use of only certain types of containers. Some of the cooking utensils used for conventional cooking may also be used in the microwave oven; however, others, especially those made the metal, an unacceptable. Metal reflects microwaves and its use can produce arcing and damage to the magnetron unit. In addition, some of the food is shielded from microwave energy while the reflected energy from the pan can overheat other parts of the food. Microwave cooking, generally, requires materials that are transparent to microwaves; the wave's pas through them, as light passes through a window, and the heat the food inside the container.

10.3.5.1 UV Radiation

- In presence of UV Radiations chemicals reactions thus induced in microorganisms can cause the failure of critical metabolic processes leading to injury or death of the microorganism. Only quanta providing energy sufficient to induce these photochemical reactions will inhibit microorganisms.
- The resistance of microorganisms to UV is largely determined by their ability to repair such damage, although some organisms such as *micrococci* also synthesize protective pigments.
- In the production of UV Radiation, low-pressure mercury vapor discharge lamps are used. 80% of their UV emission is at a wavelength of 254 nm, which has 85% of the biological activity of 260 nm. Surrounding the lamp with an absorbent glass since these wavelengths are absorbed by oxygen in the air producing ozone, which is harmful, screens out wavelengths below 200 nm.

10.3.5.2 Ionizing Radiation

Ionizing radiation has sufficient energy to eject electrons from molecules it encounters. In practice three different types of ionizing radiations are used.

1. High-energy electrons in the form of beta particles produced by radioactive decay or machine generated electrons. They are particles rather than electromagnetic radiation. Because of their mass and charge, electrons tends to be less penetrating than ionizing electromagnetic radiation.
2. X-ray generated by impinging high-energy electrons on a suitable target.
3. Gamma rays produced by the decay of radioactive isotopes.

Ionizing radiation can affect microorganisms directly or indirectly by interacting with the key molecules within the microbial cell, or inhibitory effects of free radicals produced by the radiolysis of water. These indirect effects play the more important role since absence of water doses 2-3 times higher are required to obtain the same lethality.

- Resistance to ionizing radiation depends on the ability of the organism to repair the damage caused. Inactivation kinetics is generally logarithmic, although survival curves often appear sigmoid exhibiting a shoulder and a tail to phase of log-linear death. The shoulder is very usually very slight but is more pronounced with bacteria, which have more repair mechanisms where substantially more damage can be accumulated before death ensues.
- Food associated organisms do not generally display exceptional resistance, although spores of some strains of *Clostridium botulinum* type A have the most radiation resistant spores. Since studies on food irradiation started, a number of bacteria, which are highly resistant to radiation, have been isolated and described. Although one of these, *Deinococcus radiodurans*, was first isolated from meat, their role in foods is not significant in the normal course of events.
- It had been thought that irradiation could lead to pathogens becoming more virulent but, apart from one or two exceptions, it has been found that where virulence is affected it is diminished. In the exceptions noted, the effect was slight and not sufficient to compensate for the overall reduction in viable numbers. No example has been found where a non-pathogenic organism has been converted to a pathogen as a result of irradiation.

10.4 HIGH-PRESSURE PROCESSING: PASCALIZATION

- It was Hite, who showed that high hydrostatic pressure, around 650 MPa (6500 atm), reduced the microbial load in foods such as milk, meats and fruits while working at the University of West Virginia Agricultural Experimental Station. He also noted that low PH or temperatures above and below enhance the microbial activity of a high pressure.
- Since then, microbiologists have continued to study the effect of pressure on microorganisms, although this work has focused on organisms such as those growing in the sea at great depths and pressures. When progress in industrial ceramic processing led to the development of pressure equipment capable of processing food on a commercial scale, interest in the high application of high pressure in food processing, sometimes called pascalization, lapsed until the 1980s.
- High hydrostatic pressure can have profound effects on proteins, where interactions are critical to structure and function, although the effect is variable and depends on individual protein structure. Some proteins such as those of eggs, meat and soya form gels. Other proteins are relatively unaffected and this can cause problems when they have enzymic activity limiting product shelf life. High

pressure can also affect non-protein macromolecules so that pascalized starch products often taste sweeter due to conformational changes in the starch, which allow salivary amylase access.

- Adverse effects on protein structure and activity obviously contribute to the antimicrobial effect of high pressures, although the cell membrane also appears to be an important target. Membrane lipid bilayers have been shown to compress under pressure and this alters their permeability. Bacterial endospores are more resistant to hydrostatic pressure, tolerating pressures as high as 1200 MPa. The processing time is not related to container size and there are none of the penetration problems associated with heat processing.
- At present, commercial applications of high-pressure technology has been limited to acidic. The yeasts and moulds normally responsible for spoilage in this products and pressure sensitive and the bacterial spores that survive processing are unable to grow at the low PH. Other products

10.5 LOW TEMPERATURE STORAGE: CHILLING AND FREEZING

- Temperature affects the rates of most chemical reactions likewise as the temperature is lowered so the rate decreases. The life of the food can be increased by changing the range of temperature or by storing the food at low temperature, as food spoilage is usually a result of chemical reactions mediated by microbial and endogenous enzymes. Using low temperatures to preserve food was only practicable where ice was naturally available. As early as the 11th Century BC the Chinese has developed ice houses as a mean of storing ice throughout the summer months, and these became a common features of large houses in Europe and North America in the 17th and 18th Centuries. By the 19th Century, the cutting and transporting of natural ice had become a substantial industry in areas blessed with a freezing climate.
- Chilled foods are those foods stored at temperatures near, but above their freezing point, typically 0-5°C. This commodity area has shown a massive increases in recent years as traditional chilled products such as fresh meat and fish and dairy products have been joined by a huge variety of new products including complete meals, prepared and delicatessen salads, dairy desserts and many others. Three main factors have contributed to this development. Objectives of the food manufacturers to increase value added to their products. Consumer demand for fresh foods while at the same timing requiring the convenience of only occasional shopping and ease of preparation and the availability of an efficient cold chain that is the organization and infrastructure which allows low temperatures to be maintained throughout the food chain from manufacture/harvest to consumption.

- Chill storage can change both the nature of spoilage and the rate at which it occurs. Though psychrotrophs can grow in chilled foods they do so only relatively slowly so that the onset of spoilage id delayed. In this respect temperatures changes within the chill temperature range can have pronounced effects. For example, the generation time for one pseudomonad isolated from fish was 6.7 hours at 5℃ compared with 26.6 hours at 0℃. The keeping time of haddock and cod fillets has been found to double if the storage temperature is decreased from 2.8℃ to -0.3℃.
- The ability of organisms to grow at low temperatures appears to be particularly associated with the composition and architecture of the plasma membrane. As the temperature is lowered, the plasma membrane undergoes a phase transition from a liquid crystalline state to a rigid gel in which solute transport is severely limited. The temperature of this transition is lower in psychrotophs and psychrophiles largely as a result of higher-levels of unsaturated and short chain fatty acids in their membrane lipids. If some organisms allowed to adapt to growth at lower temperatures they increase the proportion of these components in their membranes.
- Psychotropic organisms can be found in the yeasts, molds, and Gram-negative and Gram-positive bacteria. In addition to their ability to grow at low temperatures, they are inactivated at moderate temperatures. Low thermal stability of key enzymes and other functional proteins appear to be important factor, although thermostable extra cellular lipases and proteases produced by psychotropic *Pseudomonas* can be a problem in the dairy industry.
- Chilling produces cold shock causing death and injury in a proportion of the population but its effects are not predictable in the same way as heat processing. The extent of cold shock depends on a number of factors such as the organism (Gram-negatives appear more susceptible than Gram-positives), its phase of growth (exponential-phase cells are more susceptible than stationary phase cells), the temperature differential and the rat of cooling (in both cases the larger it is, the greater the damage), and the growth medium (cells grown in complex media are more resistant).
- Since chilling is not a bactericidal process, the use of good microbiological quality raw materials and hygienic handling are key requirements for the production of safe chill foods. Mesophiles that survive cooling can persist in the food for extended periods may recover and resume growth and conditions later become favorable. Thus chilling prevent an increase in the risk from mesophilic pathogens, but will not assure its elimination. Some foods are not amenable to chill storage as they suffer from cold injury where the low temperature results in tissue breakdown, which leads to visual defects and accelerated microbiological deterioration. Tropical fruits are particularly susceptible to this form of damage.
- Freezing is most successful technique for long term preservation of food since nutrient content is largely retained and the product resembles the fresh material more closely than in appetized foods.

As with chilling, freezing will not render an unsafe product safe as its microbial lethality is limited and performed toxins will persist.

- Survival rates after freezing will depend on the precise conditions of freezing, the nature of food material and the composition of its microflora. Bacterial spores are virtually unaffected by freezing, most vegetative Gram-positive bacteria are relatively resistant and Gram-negatives show that greatest sensitivity. While frozen storage does reliably inactive higher organisms such as pathogenic protozoa and parasitic worms, food materials often act as cryoprotectants for bacteria so that bacterial pathogens may survive for long periods in the frozen state.
- The extent of microbial death is also determined by the rate of cooling. Maximum lethality is seen with slow cooling where, although there is little or no cold shock experienced by the organisms, exposure to high solute concentrations is prolonged. Survival is greater with rapid freezing where exposure to these conditions is minimized. Formation of larger ice crystals are prolonged exposure to high osmotic pressure solutions during slow loss and textural deterioration on thawing, so fast freezing in which the product is at storage temperature within half an hour is the method of choice commercially. The rate of freezing in domestic freezers is much slower so, although microbial lethality may be greater, so too is product quality loss.
- Freezing and defrosting may make some foods more susceptible to microbiological attack due to destruction of antimicrobial barriers in the product and consideration, but defrosted foods do not spoil more rapidly than those that have not been frozen. Injunction against refreezing defrosted products are motivated by the loss of textural and other qualities rather than any microbiological risk that is posed.

10.6 CHEMICAL PRESERVATIVES

- Early history is evident of the chemical preservation of food and its various products. The addition of chemicals to food is not recent innovation; it is being practiced throughout the world. Pioneering work in 18th Century had been done by the chemist Jackson, and by Frederick Accum in 1820. Accum exposed a horrifying range of abuses such as the sale of sulphuric acid as vinegar, the use of copper salts to colour pickles, the use of alum to whiten bread, addition to acorns to coffee, blackthorn leaves to tea, cyamide to gives a wines a nutty flavor and red laed to color Gloucester cheese. Despite the protection of a much sticker regularly framework, occasional triumphs glycol in some Austrain wines, the intrepid entrepreneur who sold grated umbrella handles as Parmesan cheese and the grim case of the Spanish toxic cooking oil scandal which killed or maimed hundreds.
- Preservatives are defined as substances capable of inhibiting, retarding or arresting the growth of microorganisms or of any

deterioration resulting from their presence or of masking the evidence of any such deterioration. They do not therefore include substances, which act by inhibiting a chemical reaction which can limit shelf-life, such as the control of rancidity or oxidative discolouration by antioxidants like, butylated hydroxytoluene (BHE) and butylated hydroxyanisole (BHA), and the phosphates used as acidity regulators and emulsifiers in some products.

- Preservatives may be microbicidal and kill the target organisms or they may be microbistatic in which case they simply prevent them growing. This is very often a dose-dependent feature. Higher levels of an antimicrobial permitted in foods tend to be microbistatic. For this reason chemical preservatives are useful only in controlling low levels of contamination and are not a substitute for good hygiene practices.
- Usage of chemical preservatives is now more restricted and controlled than ever and in many areas it is declining. It is perhaps well to remember though that only the fairly recent advent of technologies such as canning and refrigeration has allowed as any alternative to chemical preservation or drying as a means of extending the food supply.

10.7 Organic Acids and Esters

- Organic acids such as acetic and lactic acids are produced microbiologically, although food-grade acetic acid derived petrochemically is also sometimes used as an alternative to vinegar. Organic acids can be added ingredient in formulated products such as pickles and sauces, or they can be generated in situ in the large range of lactic-fermented products. They differ from the other acids and esters that they are usually present in amounts sufficient to exert an effect on flavour and on product PH, thus potentiating their own action by increasing the proportion of undissociated acid present.
- Benzoic acid occurs naturally in cherry bark, cranberries, greengage plums, tea and arise but is prepared synthetically for food use as an antimicrobial. Its antimicrobial activity is principally in the undissociated from and since it is a relatively strong acid it is effective only in acid foods. As a consequence, its practical use is to inhibit the growth of spoilage yeasts and moulds. Activity against bacteria has been reported but they show greater variability in their sensitivity.
- Parabens (para-hydroxybenzoic acid esters) differ from the other organic acids described in the respects that they are phenols rather than carboxylic acids. They are much weaker acids and so are predominantly uncharged even at netural PH. This means that they can be used effectively in non-acidic foods. Their antimicrobial acitivity decreases their water solubility and may lead to poor performance in some foods where partition into the fatty phase may occur. These act mainly at the cell membrane eliminating the PH component of the proton motive force and affecting energy transduction and substrata transport. In contrast to other weak acid

preservatives, there is little evidence suggesting that parabens interfere directly with specific enzymic activities.

- Sorbic acid is an unsaturated fatty acid, found naturally in the berries of the mountain ash. It shows same PH dependency of activity as other organic acids and active against catalase-negative bacteria. This has led to it use as a selective agent in media for *Clostridia* and lactic acid bacteria and as a fungal inhibitor in lactic acid fermentations.
- The membrane is an important target of sorbic acid, although inhibition of a number of key enzymes of intermediary metabolism, such as enolase, lactate dehydrogenase and several Kerbs cycle enzymes, has been shown. In contrast to its use as a selective agent for *Clostridia,* it has been shown that sorbic acid inhibits the germination and outgrowth of C. *botulinum spores*.
- Porptonic acid occurs in a number of plants and is also produced by the activity of propionibacteria in certain cheeses. It is used as a mould inhibitor in cheese and baked products where it inhibits rope-forming bacilli.

1. Nitrite

In the year 1920 the antibacterial action of nitrite was described. Though it had long been employed unknowingly in the production of cured meats where it is also responsible for their characteristic flavor and colour. In early curing processes nitrite was produced by the bacterial reduction of nitrite present as an impurity in the crude salt used, but now nitrite, or more commonly nitrite itself, is added as the sodium or potassium salt. It inhibits a wide range of microorganisms including *Escherichia*, *Flavobacterium*, *Micrococcus*, *Pseudomonas* and others, although *Salmonella* and *Lactobacillus* were more resistant. Of most practical importance though is the ability of nitrite to inhibit spore-forming bacteria such as *Clostridium botulinum*, which will survive the heat process applied to many cured meats. The mechanism of its action is poorly understood party due to the complexity of the interaction of several factors such as pH, salt content, presence of nitrite and the heat process applied due to cured meat.

With the decrease in pH value, the bacterial inhibition by nitrite increases suggesting that nitrous acid is the active agent. In the case of spores, it appears that nitrite acts by inhibiting germination and outgrowth of heated spores and by reacting with components in the product to form other inhibitory compounds. When nitrite was heated in certain bacteriological media, the resulting medium proved inhibitorier to *Clostridia* than when filter-sterilized nitrite was added after heating.

The use of nitrite and nitrate in food has attracted scrutiny since it was discovered in the 1950s that N-nitrosamines, formed by the reaction of nitrite with secondary amines, especially at low pH, could be carcinogenic. Concern developed that they may present in food or formed in the body as a result of ingestion of nitrate or nitrite with foods. Curved

meats, particularly fried bacon, beer and, in some countries, fish, makes the most significant contribution to dietary intakes of nitrosamines. Nitrite is also of concern since it can be reduced to nitrite by the body's own microflora. Cured meats are not a significant source; vegetables contribute more than 75% of the dietary intake of nitrate, although water can be an important source in some areas.

Awareness of the problem has led to changes in production practices for cured meats such as the use of low levels of nitrite in preference to nitrite and the increased use of ascorbic acid, which inhibits the nitration reaction. These measures have produced significant reductions in nitrosamine levels.

Nitrite also contributes to the typical cured meat flavour. Taste panels can distinguish cured meats where nitrite has not been used but the precise reasons for this are not known. It is thought that nitrite acts as an antioxidant to inhibit lipid degradation in the meat although this may only be part of the story.

2. **Sulphur Dioxide**

Sulphur dioxide (SO_2) has known from the ancient times dur to its reputation for its disinfecting properties and its earliest use in the food industry was when Sulphur candles were burnt to disinfect the vessels used to produce and store wine. Nowadays, it is also used as an antioxidant to inhibit enzymic and non-enzymic browning reactions in some products. Sulphur dioxide is a colorless gas that readily dissolves in water to establish a pH dependent equilibrium similar to CO_2.

The unionized forms of SO_2, which can readily penetrate the cell, have the greatest antimicrobial activity. Since the unionized forms predominate at low pH values, it follows that SO_2 is used to best effect in acidic foods. At neutral pH, it is present as a mixture of the relatively inactive bisulfite and sulphite ions, although salts of these anions prove the most convenient way of handling the preservative in the food industry.

SO_2 is a reactive molecule and can disrupt microbial metabolism in a number of ways. As a reducing agent, it can break disulfide linkages in proteins and interfere with redox processes. It can also form addition compounds with pyrimidine bases in nucleic acids, sugars and a host of key metabolic intermediates. It is able to destroy the vitamin thiamine in foods. Sulphur dioxide is active against bacteria, yeasts, and moulds, although some yeasts and moulds are more resistant. Gram-negative bacteria are most susceptible. Seasonal surpluses of soft fruits are also preserved by the addition of high levels of SO_2 to permit jam production throughout the year.

10.8 NATURAL FOOD PRESERVATIVES

- Any form of preservation, which prevent or delays the recycling of the elements in plant and animal biomass is referred as unnatural. Smoking of foods might be viewed as a natural method of preservation. Its antimicrobial effect is a result of drying and the

activity of wood-smoke components such as phenols and formaldehyde, which would probably not be allowed, were they to be proposed as chemical preservatives in their own right.

- The use of natural food components possessing antimicrobial activity such as essential oils and the lactoperoxidase system in milk has attracted the attention of food microbiologists in this respect. The use of Nisin can be extended by expedients such as inclusion of whey fermented by a nisin-producing strain of Lactococcus lactis as an ingredient in formulated products like prepared sauces.

I. Antibiotics and Food Preservation

* Antibiotics preserve foods too. Meat is among the most expensive and perhaps the most relished item of food. Even if it is slightly contaminated with bacteria during slaughtering and distribution, putrefaction and decay set in very rapidly, causing a great deal of economic loss. Therefore, in order to prevent such spoilage antibiotics such as streptomycin and penicillin are used. They are infected into the blood vessels of the animal either before or after slaughter. They can also be sprayed on the surface of the raw meat.
    * Greater care is required in the preservation of fish in comparison to meat. From the time of catching till it is sold at the counter, it takes considerably long time. This is particularly true of cod and haddock, which are caught in deep water seas and take quite some time to be brought ashore. Even when kept in ice, they cannot normally be preserved for more than seven days. This causes heavy loss to the fish industry. By the time it reaches the counter another food bit of it will have decayed. Since a number of bacteria thrive even a temperatures as low as 0° to 5℃ fish is still on board the ship id dipped in the antibiotic solution. It is then packed in ice containing the antibiotic and stored away in chilled (-1 to 1℃) seawater. U.S.A has built fishing ships, which are specially fitted with antibiotic containing tanks and refrigerated stores.
    * Since the yeasty, old or stale, smell of antibiotics disappears during cooking the objection to food preservation using antibiotics disappears. Though primarily of chemotherapeutic uses, the antibiotics have already given sufficient proof of their value to humanity in other fields as well.

II. MODIFICATION OF ATMOSPHERE

* In the 19th Century, it was believed that the air is the main factor responsible for the putrefaction of the food. Some preservation techniques, such as covering a product with a melted fat and allowing it to set, did in fact rely on the exclusion of air but it is only in the last 30 years or so that shelf-life extension techniques based on changing the gaseous environment of a food have really come to be widely used.
* Modified atmospheres exert their effect principally through the inhibition of fast growing aerobes that would otherwise quickly spoil perishable products. Obligate and facultative anaerobes such as *Clostridia* and the Enterobacteriaceae are less affected. Thus

keeping quality is improved but there is generally little effects on pathogens, if present, and the technique is invariably applied in conjunction with refrigerated storage. In practice three different procedures are used to modify the atmosphere surrounding a product: vaccum packing, modified-atmosphere packing or gas flushing, and controlled atmospheres.

* The packaging materials used are usually plastic laminates in which the innermost layer is polyethylene, which has good heat-sealing properties. Mechanism closures on packs are far less effective as they often leave channels through which high rates of gas exchange can occur. Overlying the layer of polythene is usually another layer with much better gas barrier properties. No plastics are completely impermeable to gases, although the extent of gas transmission across a plastic film will depend on the type of plastic, its temperature, the film thickness and the partial pressure difference across the film.
* In vaccum packing the product is placed in a bag from which the air is evacuated, causing the bag to collapse around the product before it is sealed. Residual oxygen in the pack is absorbed through chemical reactions with components in the product and any residual respiratory activity in the product and its microflora. To achieve the best results, it is important that the material to be packed has a shape that allows the packaging film to collapse on to the product surface entirely without pockets and without the product puncturing the film.
* Vaccum packing has been used for some years for primal cuts of red meats. At chill temperatures, good quality meat in a vaccum pack will keep up to five times longer than aerobically stored meats. The aerobic microflora normally associated with the spoilage of conventionally stored meats is prevented from growing by the high levels of CO_2, which develop in the pack after sealing and the low oxygen tension. The microflora that develops is dominated by lactic acid bacteria, which are metabolically less versatile than the gram-negative aerobes, grow more slowly and reach a lower ultimate population.
* In recent years vaccum packaging has been increasingly used for retail packs of products such as cooked meats, fish and prepared salads. Oxygenation occurs very rapidly on opening a vacuum pack and the meat assumes the more familiar bright red, fresh meat appearance of oxymyoglobin. Cured meats, on the other hand, are often vacuum packed for display since the cured meat pigment nitrosomyoglobin is protected from oxidation by vacuum packing.
* The expanding range of chilled foods stored under vacuum and the availability of vacuum packing equipment for small-scale catering and domestic use has prompted concern about increasing the risk from psychrotrophic *Clostridium botulinum*. In modified atmosphere packing, a bulk or retail pack is flushed through with a gas mixture usually containing some combination of carbon dioxide, oxygen and nitrogen. The composition of the gas atmosphere changes during storage as a result of product and microbial respiration, dissolution of CO_2 into the aqueous phase,

and the different rates of gas exchange across the packing membrane. Increasing the ratio of pack volume to product mass although this is not often practicable for other reasons can reduce these changes.

10.9 CONTROL OF WATER ACTIVITY

* Water is the basic component of the food commodities and the water activity is the main cause of spoilage of food. The water activity of a product can be reduced by physical removal of liquid water either as vapour in drying, or as a solid during freezing. It is also lowered by the addition of solutes such as salt and sugar. The primary role of these techniques in food preservation has been alluded to in a number of places. It was the earliest food preservation techniques and, until the 19^{th} Century, water activity reduction played some part in almost all the known procedures for food preservation.
* Solar drying while perhaps easy and cheap is, in many areas, subject to the vagaries of climate. Drying indoors over a fire was one way to avoid this problem and one, which had the incidental effect of imparting a smoked flavour to the food as well as the preservative effect of chemical components of smoke. Traditional dried and salted products persist in the modern diet such as dried hams and hard dry cheeses but the more recent development and applications of techniques such as refrigeration, and heat processing and the preference for ‘fresh’ foods has meant that their popularity has declined. Nevertheless this should not obscure the important role that low aw, foods still play in our diet in the form of grains, pulses, jams, bakery products, dried pasta, dried milk, instant snacks, desserts, soups etc.
* Microorganisms that were in the product before drying or were introduced during processing can survive for extended periods. This is most important with respect to pathogens. If they were present in hazardous numbers before drying or if time and temperature allow them to resume growth in the product that is rehydrated before consumption, then they grow in number and cause hazards. There have been a number of instances where the survival of pathogens or their toxins has caused problems in products such as chocolate, pasta, dried milk and eggs. Generally Salmonella and Staphylococcus aureus have been the principal pathogens involved there have been 17 major outbreaks associated with these organisms and dried milk in the last 40 years, but spore formers are particularly associated with some other dried products such as herbs or rice.
* There are a number of procedures for mechanical drying, which are quicker, more reliable and more expensive than solar drying. With the exception of freeze-drying where the product is frozen and moisture sublimed from the product under vacuum, these techniques employ high temperatures. During drying a proportion

of the microbial population will be killed and sub-lethally injured to an extent, which depends on the drying technique and the temperature regime used. Although the air temperature employed in a drier may be very high, the temperature experienced by the organisms in the wet product is reduced due to evaporative cooling. As drying proceeds and the product is reduced due to increases, so too does the heat resistance of the organisms due to the low water content. In spray drying, the milk is pre-concentrated to about 40-45% solids before being sprayed into a stream of air is heated to temperature up to 260°C at the top of a tower. The droplets dry very rapidly and fall to tye base of the tower where they have collected. In drum drying, the milk is spread on the surface of slowly rotating metal drums, which are heated inside by steam to temperature of about 150°C. The film dries as the drum rotates and is scrapped of as a continuous sheet by a fixed blade close to the surface of the drum. Although it uses a lower temperature, drum drying gives greater lethality since the milk is not subject to the same degree of pre-concentration used in spray-dried milk and the product spends longer at high temperatures in wet state. Spray drying is however now widely used for milk drying because it produces a whiter product, which is easier to reconstitute, and has less of a cooked flavour. Milk is pasteurized before drying although there are opportunities for contamination during intervening stages.

The limited lethality of drying processes and the long storage life of dried products mean that manufacturers are not exempt from the stringent hygiene requirements of other aspects of food processing. Good quality raw materials and hygienic handling prior to drying are essential.

10.10 COMPARTMENTALIZATION

- The best method for the preservation of food is compartmentalization. Butter is an example of a rather special form of food preservation where microbial growth is limited by compartmentalization within the product. In common, there are two types of butter that is sweet cream butters, which are often salted, and ripened cream butters. In ripened-cream butters, the cream has been fermented by lactic acid bacteria to produce inter alia action from the fermentation of citrate, which gives a characteristically buttery flavour to the product. They have stronger flavour than sweet-cream butters but are subject to faster chemical deterioration. Sweet-cream butter is most popular in the United States, Ireland, the UK, Australia and New Zealand whereas the ripened cream variety is more popular in continental Europe.
- Traditional farmhouse butter-making used wooden butter churns and these were originally scaled up for the earliest commercial butter making. However the impossibility of effectively cleaning and sanitizing wood has led to its replacement by churns made of stainless steel or aluminum-magnesium alloys. After the butter has formed, the buttermilk is drained off, the butter grains washed with water and, in the case of sweet-cream butter; salt is added. The butter is then 'worked' to ensure further removal of moisture and an

even distribution of salt and water throughout the fat phase. In those that do contain microorganisms, the nutrient supply will be severely limited by the size of the droplet. If the butter is salted, the slat will concentrate in the aqueous phase along with bacteria, which will therefore experience a higher more inhibitory salt level.

* Few microorganisms survive pasteurization so the microbiological quality of butter depends primarily on the hygienic conditions during subsequent processing, particularly the quality of water is used to wash the butter. Good microbiological quality starting materials are essential though, as performed lipases can survive pasteurization and rapidly spoil the product during storage. Butter spoilage is most often due to the development of chemical rancidity but microbiological problems do also occur in the form of cheesy, putrid or fruity odours or the rancid flavour of butlytic acid produced by butter fat hydrolysis. *Pseudomondas* are the most frequently implicated cause and are introduced mainly in the wash water. Psychrotrophic yeasts and moulds can also cause lipolytic spoilage and these are best controlled by maintain low humidity and good air quality in the production environment and by ensuring the good hygenic quality of packaging materials. In this respect aluminium foil wrapper; are preferred to oxygen permeable parchment wrappers, as they will help discourage surface moulds growth.

10.11 UNIT- END- EXERCISES

Which of the following strain(s), that grow in the jellies and candid fruits, are able to grow in sugar concentration upto 67.5%?

A. *Aspergillus*

B. *Penicillium*

C. *Citromyces*

D. All of these

Flat sour spoilage of acid foods is caused by

A. *B. coagulans*

B. *B. pepo*

C. both (a) and (b)

D. *B. stearothermophillus*

The most important kind of chemical spoilage of canned foods is the hydrogen swell which is favored by

A. increasing acidities of foods

B. increasing temperature of storage

C. imperfection in the tinning and lacquering

D. all of these

The immediate source of the flat sour bacteria is usually the

A. plant equipment

B. Sugar

C. Starch

D. Soil

10.11 SUGGESTED READINGS

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UNIT XI – FOOD BORNE DISEASES

11.1. Introduction
11.2. Objectives
11.3. Food borne illness (Bacterial)
11.4. Food borne poisoning
11.5. Non bacterial infections and intoxication
11.6. Control bacteria
11.7. Questions
11.8. Suggested Readings

1.1INTRODUCTION

In the recent decades, a global effort from food suppliers, industries, and governments has ensured that food production would meet the high quality required by the sanitary authorities, minimizing public health implications and economic losses caused by food-borne diseases. Several programmes and initiatives have been developed worldwide both by government agencies and the private sector to achieve this goal. Food-borne diseases, caused by pathogens, natural toxins, and chemical contaminants, remain a global public health challenge, since new threats are continuously emerging while others are being controlled. Also, in many countries, the consumption of food prepared outside the home increases the exposure to the risks posed by poor hygiene in food service. In this context, a reliable sanitary surveillance system is urgently needed to identify potential hazards, conduct risk analysis, and control food-borne diseases outbreaks worldwide

1.2 OBJECTIVES

After going through this unit, you should be able to:

- To study the microbial illnesses
- To identify the bacterial and non-bacterial microbes
- Elaborate upon the concept of Bacterial infections

11.3 What are foodborne illnesses?

- When certain disease-causing bacteria or pathogens contaminate food, they can cause foodborne illness, often called “food poisoning”. Foods that are contaminated may not look, taste or smell any different from foods that are safe to eat. Salmonella, Campylobacter, Listeria and Escherichia coli (E. coli) are the most common bacteria causing foodborne illness. Unfortunately, some foodborne bacteria such as Bacillus cereus produce toxins that are heat-resistant, which means they cannot be destroyed by cooking. The virus that most commonly causes gastrointestinal illness is the Norovirus which can be

transmitted through contaminated food or water, as well as contaminated surfaces such as sinks, tables, handrails etc. Foodborne illness can be serious or even fatal.

- Some food-borne disease outbreaks are not caused by bacteria or their toxins but results from mycotoxins, viruses, rickettsias, parasitic worms, or protozoa or from the consumption of food contaminated with toxic substances. The implication in human health is not clearly understood for the mycotoxins or for many of the viruses, but their incidence and the nature of their action in animals justify their discussion.

11.3.1 Which food is preferred by foodborne bacteria?

Bacteria grow and multiply on some types of food more easily than on others. The types of foods which bacteria prefer include:

- Meat
- Poultry
- Dairy products
- Eggs
- Seafood
- Cooked rice
- Prepared fruit and
- Potato salads.

These foods are more likely to be infected by foodborne bacteria but other foods can also be infected or cross-contaminated by them if appropriate food safety measures are not taken during preparation, storage, transportation and handling of ready-to-eat foods.

11.3.2 Who are at risk?

Some people are at a higher risk for developing foodborne illness. These include pregnant women, young children, older adults, and people with weakened immune systems.

11.3.3 How foodborne illnesses occur

Foodborne illnesses follow within 1–3 days after consumption of contaminated food during a party or festival. It often occurs in clusters where persons serve themselves rather than being served by a single server. The following conditions may be responsible for a foodborne illness:

- Not cooking food thoroughly (particularly meat and meat products); • not storing food that needs to be chilled at below 5 °C correctly;
- keeping cooked food unrefrigerated for more than an hour;

• eating food that has been touched by someone with diarrhea and vomiting;

• Cross-contamination, such as placing cooked food on a plate that had raw meat.

11.3.4 What are the clinical symptoms?

Foodborne illnesses causes some combination of nausea, vomiting, and diarrhea that may or may not be bloody, sometimes with other symptoms. After eating tainted food, abdominal cramps, diarrhea, and vomiting can start as early as one hour or within three days depending on the foodborne pathogen, type of toxin and level of food contamination.

11.3.5 Which are common causes of foodborne illnesses and what are the risk factors and possible clinical symptoms

Salmonella is the most common cause of foodborne illness and meat, egg and seafood are its common sources. The important causes of foodborne illness in details are presented in Table 1 what are common tips for preventing foodborne illnesses

A few simple actions can cut the likelihood of foodborne illness drastically! Please follow WHO's five keys to safer food;

- **Keep clean:** Thoroughly wash raw fruits and vegetables with tap water. Keep clean hands, kitchen and chopping board all the time.
- **Separate raw and cooked food:** Do not mix raw food and ready-to-eat food. Do not mix raw meat, fish and raw vegetables.
- **Cook thoroughly:** Thoroughly cook all meat, poultry and seafood, especially shellfish. Reheat all leftovers until they are steaming hot. From farm to plate, make food safe
- **Keep food at safe temperatures:** Refrigerate cooked food within two hours of preparation. Never defrost food at room temperature. Defrost frozen food in the refrigerator, cold water or in the microwave.
- **Use safe water and raw materials:** Use safe drinking water for food preparation. Check use-by dates and labels while buying packed food.

Table 1: Bacterial Food Borne Illnesses

Foodborne Illnesses (Bacterial)

Etiology	Incubation Period	Signs and Symptoms	Duration of Illness	Associated Foods	Laboratory Testing	Treatment
Bacillus anthracis	2 days to weeks	Nausea, vomiting, malaise, bloody diarrhea, acute abdominal pain.	Weeks	Insufficiently cooked contaminated meat.	Blood.	Penicillin is first choice for naturally acquired gastrointestinal anthrax. Ciprofloxacin is second option.
Bacillus cereus (preformed enterotoxin)	1–6 hrs	Sudden onset of severe nausea and vomiting. Diarrhea may be present.	24 hrs	Improperly refrigerated cooked or fried rice, meats.	Normally a clinical diagnosis. Clinical laboratories do not routinely identify this organism. If indicated, send stool and food specimens to reference laboratory for culture and toxin identification.	Supportive care.
Bacillus cereus (diarrheal toxin)	10–16 hours	Abdominal cramps, watery diarrhea, nausea.	24–48 hours	Meats, stews, gravies, vanilla sauce.	Testing not necessary, self-limiting (consider testing food and stool for toxin in outbreaks).	Supportive care.
Brucella abortus, *B. melitensis*, and *B. suis*	7–21 days	Fever, chills, sweating, weakness, headache, muscle and joint pain, diarrhea, bloody stools during acute phase.	Weeks	Raw milk, goat cheese made from unpasteurized milk, contaminated meats.	Blood culture and positive serology.	*Acute:* Rifampin and doxycycline daily for $\geq$6 weeks. Infections with complications require combination therapy with rifampin, tetracycline, and an aminoglycoside.
Campylobacter jejuni	2–5 days	Diarrhea, cramps, fever, and vomiting; diarrhea may be bloody.	2–10 days	Raw and undercooked poultry, unpasturized milk, contaminated water.	Routine stool culture; *Campylobacter* requires special media and incubation at 42°C to grow.	Supportive care. For severe cases, antibiotics such as erythromycin and quinolones may be indicated early in the diarrheal disease. Guillain-Barré syndrome can be a sequela.
Clostridium botulinum—children and adults (preformed toxin)	12–72 hrs	Vomiting, diarrhea, blurred vision, diplopia, dysphagia, and descending muscle weakness.	Variable (from days to months). Can be complicated by respiratory failure and death.	Home-canned foods with a low acid content, improperly canned commercial foods, home-canned or fermented fish, herb-infused oils, baked potatoes in aluminium foil, cheese sauce, bottled garlic, foods held warm for extended periods of time (eg, in a warm oven).	Stool, serum, and food can be tested for toxin. Stool and food can also be cultured for the organism. These tests can be performed at some state health department laboratories and CDC.	Supportive care. Botulinum antitoxin is helpful if given early in the course of the illness. Contact the state health department. The 24-hour number for state health departments to call is (770) 488-7100.
Clostridium botulinum—infants	3–30 days	In infants <12 months, lethargy, weakness, poor feeding, constipation, hypotonia, poor head control, poor gag and sucking reflex.	Variable	Honey, home-canned vegetables and fruits, corn syrup.	Stool, serum, and food can be tested for toxin. Stool and food can also be cultured for the organism. These tests can be performed at some state health department laboratories and CDC.	Supportive care. Botulism immune globulin can be obtained from the Infant Botulism Prevention Program, Health and Human Services, California (510-540-2646). Botulinum antitoxin is generally not recommended for infants.
Clostridium perfringens toxin	8–16 hrs	Watery diarrhea, nausea, abdominal cramps; fever is rare.	24–48 hrs	Meats, poultry, gravy, dried or precooked foods, time- and/or temperature-abused food.	Stools can be tested for enterotoxin and cultured for organism. Because *Clostridium perfringens* can normally be found in stool, quantitative cultures must be done.	Supportive care. Antibiotics not indicated.
Enterohemorrhagic *E. coli* (EHEC) including *E. coli* O157:H7 and other Shiga toxin-producing *E. coli* (STEC)	1–8 days	Severe diarrhea that is often bloody, abdominal pain and vomiting. Usually, little or no fever is present. More common in children <4 years.	5–10 days	Undercooked beef especially hamburger, unpasteurized milk and juice, raw fruits and vegetables (eg. sprouts), salami (rarely), and contaminated water.	Stool culture; *E. coli* O157:H7 requires special media to grow. If *E. coli* O157:H7 is suspected, specific testing must be requested. Shiga toxin testing may be done using commercial kits; positive isolates should be forwarded to public health laboratories for confirmation and serotyping.	Supportive care, monitor renal function, hemoglobin, and platelets closely. *E. coli* O157:H7 infection is also associated with hemolytic uremic syndrome (HUS), which can cause lifelong complications. Studies indicate that antibiotics may promote the development of HUS.

11.4. FOOD BORNE POISONING

11.4.1 Mycotoxins

Mycotoxins are fungal metabolites. Some are highly toxic to many animals and potentially toxic to human being. Recent concern is related to their carcinogenic properties and their presence in many food items.

11.4.2 Fungi and Human Beings

The fungi include the molds, yeasts, mildews, blights, rusts, and mushrooms. The metabolite of *Penicillium chrysogenum*, penicillin, has contribute immensely to human well-being. Some mushrooms are harmful or poisonous to humans, but in contrasts, molds have generally been regarded as harmless. Many fungi can be isolated from plants, including *Alternaria*, *Rhizopus*, *Fusarium*, *Cladosporium*, *Helminthosporium*, and *Chaetomium*. The two predominant genera of fungi is stored products are probably *Penicillium* and *Aspergillus*, members of which produce mycotoxins.

11.4.2.1 Aflatoxin

A common factor in each of these episodes was the use of Brazilian peanut meal as part of the animal feed. *Aspergillus flavus* was isolated from the meal, and subsequently a toxic metabolite, or toxin, was isolated and identified. The resulting A. *flavus* toxin was called **aflatoxin**. Aflatoxins are produced by certain strains of *Aspergillus flavus* and *A. parasiticus* and other Table. Just because a fungus is identified as *A. flavus* or *A. parasiticus* does not mean it will produce aflatoxin. The genus Aspergillus is divided into morphologically distinguishable groups, one of which is the A. *flavus* group, containing the species A. *flavus* and A. *parasiticus*. Both species will grow on a wide variety of substrates over a mesophilic range of temperatures. Optimal conditions for the production of aflatoxin would be an a_w of 0.85and a temperature of 25 to 40 C.

(a) Chemistry: The two major metabolites or aflatoxins have been designated B_1 and G_1 because they fluoresce blue (B_1) and green (G_1) when exposed to long-wave ultra-voilet light. Aflatoxins B_2 and G_2 are the dihydroderivatives of B_1 and G_1 (Figures 25.1). Other closely related aflatoxins include B_2a, G_2a, and GM_1. Aflatoxins M_1, M_2, and P_1 are the hydroxylated derivatives of B_1 and B_2 which are excreted in the urine, feces, and milk as metabolic products of B_1 and B_2 following their consumption by mammals.

(b) Toxicity: Aflatoxin $B_{1,}$ the most toxic of the aflatoxins, is toxic to various animals, are summarized in Table 25.1. Many of the other aflatoxins have been shown to be toxic or carcinogenic to different species of the fish, mammals, and poultry. When cows eat feed containing aflatoxin, aflatoxin M_1 and M_2 is excreted in the milk. Although M_1 and M_2 are less toxic than the parent compounds B_1 and B_2, M_1 retains its toxic and carcinogenic ability in many animals.

(c) Significance in Foods: Many commodities will support the growth of toxigenic strains if inoculated, including various dairy products, bakery products, fruit juices, cereals, and forage crops.

In most cases, the growth of a toxigenic strain and the elaboration of aflatoxin occurs following harvesting or formulation of the product. Peanuts, cottonseeds, and corn, however, differ significantly in that these products are susceptible to fungal invasion, growth, and mycotoxin production before harvesting. The contamination and potential for aflatoxin production in these crops is related to insect damage, humidity, weather conditions; and agricultural practices.

Table 2: Mycotoxins that May be Significant in Foods

Mycotoxin	Some molds producing the toxin	Foods or feeds isolated from	Animals affected	
			Toxic to	Carcinogenic to

Aflatoxins	Aspergillus flavus, A. parasiticus, some Peculium	Barley, corn, cottonseed, millet, oats, peanuts, peanut meal, peanut butter, rice, soybeans, wheat, spaghetti, cassava, cottonseed meal, cowpeas, sorghum, peas, sesame, soybean meal, sweet potatoes	(B1) quail, cats, chickens, pheasants, salmon, rabbits, monkeys, dogs, hamsters, turkeys, mink, cattle, guniea pigs	(B1) trout, rats, sheep, mice, ducklings
Patulin	Pencillium expansum, P. claviforme, P. patulam, p. melinii, P. leucopus, P. equinum, P. cyclopium, Aspergillus clavatus, A. giganteus, A. terreus	Apple sap, apple cider, apple juice	Mice, rats, cats, rabbits, quail, guppies, brine, shrimp	Mice
Ochratoxin A	Aspergillus ostianus, A. petrakii, A. alliaceus, A. sclerotiorum, A. sulphureus, A. melleus, Penicillium cyclopium, P.	Corn, wheat, barley, white beans, peanuts, dough, bread, hen's eggs	Rats, chicks, ducklings, trout	Rats, trout, chicks

	purpurescens, P. commune, P. viridicatum			
Luteoskyrin	Penicillium islandicum	Mold, rice flour	Mice	Mice
Sterigmatocystin	Aspergillus regulosus, A. nidulans, A. versicolor, Pencillium luteum	Wheat, oats	Mice, monkeys, rats	Rats
Pencillium acid	Pencillium puberulum, P. cyclopium, P. marteusii, P. thomii, P. suavolens, P. madriti, P. baarneuse,	Dried beans, tobacco	Rats	Rats
Alimentary toxic aleukia (ATA)	Species of Cladosporium, Penicillium, Fusasrium, Mucor, Alternaria	Grain	Human beings	-
Roquefortine	Pencillium roqueforti	Blue cheese, Roquefort cheese, Stitlon cheese	Mice	-

11.4.2.2 Patulin

First isolated and described as an antibiotic, patulin is structurally synonymous with expansin, penicidin, claviformin, clavatin, clavacin, mycoin C, and gigantic acid. Several molds have been reported to produce patulin, as shown in Table 3.

(a) Chemistry: Patulin in the pure state is a white crystal with a melting point of 110.5 C and a molecular weight of 154. It is sensitive to SO_2 and is unstable in alkali but stable in acid.

(b) Toxicity: Originally isolated as an antibiotic, it is effective against many bacterial species. Concentrations as low as 0.1 percent completely inhibit *E. coli* and *S. aureus*. It also exhibits strong fungistatic activity and is toxic to seeds and seedling of higher plants including sugar beets, corn, wheat, peas, tomato, cucumber, and flax.

(c) Significance in Foods: Many patulin-producing strains have been isolated from food and animal feeds. The presence of patulin has been detected in apple cider and apple juice. Its occurrence in apple products may be related to the fact that over 60 percent of sampled rotted apples have yielded patulin-producing strains of *Penicillium expansum.* In most other products patulin-producing molds represent only small percentage of the total isolates. Another explanation for the inability to detect patulin chemically in foosd stuffs which support good growth of patulin-producing fungi might be the observed inhibitory effect of several food compounds of patulin.The carcinogenic property of patulin in animals, the isolation of patulin-producing fungi from several foodstuffs, its inactivation in some foods, the potential for toxin production at refrigeration temperatures, and its stability to heat suggest that patulin will be the subject of further study and concern in the food industry.

11.4.2.3 Ochratoxin

Published work on the aflatoxins and suggestions of a correlation between mold metabolities and a high incidence of liver cancer in the Bantu population of South Africa provided the impetus for investigation of the presence of mycotoxins in the cereal grains of that region. Scott (1965) isolated twenty-two fungi (seven species) which were toxic to ducklings, rats, or mice. Subsequently a toxi metabolite of Aspergillus ochraceus was isolated, identified, and named ochratoxin A. other ochratoxin A-producing molds have been noted .

(a) Chemistry: Ochratoxin A is a structurally a chlorinated isocoumarin derivative with an amide bond to phenylalanine. A dechloro analog of this compound has also been isolated and named ochratoxin B. Ochratoxin A fluoresces green under ultraviolet light, and ochratoxin B fluoresces blue.

(b) Toxicity: Ochratoxin A is toxic to ducklings, rats, chicks, trout, and other animals. It is one-third as toxic as aflatoxin B_1 to rats. The other derivatives or analogs are all equally toxic or less toxic than ochratoxin A. they have been shown to produce lesions in the kidneys of rats and lesions in trout and chicks. Mold nephrosis, a disease in pigs, has occurred at high rates when the animals were fed grain which had been harvested wet. There is a speculation that molds producing ochratoxin A and citrinin are responsible for this syndrome.

(c) Significance in Foods: In addition to their unknown effect on human beings, the ochre toxins are of interest in foods for at least three reasons:

- They are toxic to some animals
- Some are very heat resistant
- Many ochre toxin and citrin in-producing fungi are capable of growth and mycotoxin production at temperatures below 10 C
- Ochre toxins have been isolated from numerous foods

11.4.2.4 Luteoskyrin

Penicillium islandicum produces two metabolities, luteoskyrin and cyclochlorotine, which are hepatotoxic to some animals. Although luteoskyrin is not as carcinogenic as aflatoxin B_1, mice seem to be more sensitive to luteoskyrin than to aflatoxin $B_{1.}$ There are no known acute human intoxications attributed to luteoskyrin or cyclochlorotine.

11.4.2.5 Sterigmatocystin

Structurally similar to aflatoxin, sterigmatocystin has a carcinogenic potency probably between one-tenth and one-hundredth of that of aflatoxin.

11.4.2.6 Penicillic Acid

Several molds have been reported to produce penicillic acid, and its carcinogenic ability has been noted. Many commodities, including oats, wheat, rice, corn, and barley, support the growth of penicillic acid-producing strains.

11.4.2.7 Alimentary Toxic Aleukia (ATA)

The syndrome in human is caused by the toxic metabolities fusariogenin, epicladosporic acid, and fagiclodoscorpic acid. ATA is not a problem if grain in harvested and stored properly. Previous outbreaks have all resulted from the consumption of overwintered grain, i.e., grain that has been allowed to remain in the fields during the winter and harvested late.

11.4.2.8 Roquefortine

A toxic substance has recently been detected in commercial blue cheese from several countries. Heavily molded portions of the cheese contain higher concentrations that the white portions, suggesting that *Penicillium roqueforti* may be producing a mycotoxin during curing of Roquefort cheese (blue cheese).

11.4.2.9 Implications

The above list of mycotoxins is far from complete. Since the isolation and characterization of the aflatoxins, much information has been published on a large number of diverse toxic metabolities of fungal origin.

Most of the studies on the toxicological and carcinogenic effects of the mycotoxins have, of course, been made with experimental animals, with limited or nonexisting data on human beings. Therefore, clinical evidence and the effects on mycotoxins on people essentially not known. The possible wide range of the effects and susceptibility to carcinogens may make it impossible ever to establish safe dose levels of the mycotoxins in human foods.

The abundance of surveys and field and storage studies has definitely established the presence of many of the mycotoxins in our food supply. The actual impact on human health and its long-term implications are still being established. Some common characteristic of viruses are that they are

* Ultramicroscopic in size, varying from 10 to 450 mm
* Able to pass through most bacterial filters (i.e., 0.22 μm)
* Cultivatable only on a susceptible host cell line
* Incapable of reproduction without a host
* Able to infect people, animals, plants or bacteria

Viruses consists of a core of nucleic acid, either deoxyribonucleic acid (RNA), and protein coat. When the virus particles are invades a susceptible host cell (the intracellular state), the nucleic acid core and the protein coat separate. There are two possible responses of the viral nucleic acid in the host cell. In most instances the viral nucleic acid serves as the template to direct the host cell machinery to synthesize new virus particles.

(a) Classification

- The host in which the virus multiplies
- The type of tissue or organs of primary infections
- The mode of transmission

More recent taxonomical approaches include consideration of

- The nucleic acid present, i.e., RNA or DNA
- Symmetry
- Presence or absence of an envelope
- Diameter of the helical nucleocapsids
- Base sequence of the nucleic acid

Numerous viral infections may be result in the death of animals or the destruction of plants. This consequence should be considered a reduction of potential foods available for humans. In addition, many of the animal viruses can cause disease in humans.

Many of the enteroviruses, including the coxsackie viruses and ECHO viruses, may result in human gastroenteritis. Several viruses are implicated in food-borne outbreaks, their mode of transmission, and measures to prevent their spread are summarized in Table 25.2. Further clarification of possible relationships is hampered by the lack of practical laboratory methodology for detection and isolation of viruses from foods.

11.4.2.10. Infectious Hepatitis

The hepatitis virus enters a person through the oral route normally as a result of fecal contamination of water or food. The incubation time (onset of symptoms) is long (see Table 25.2) but eventually may result in serious liver complications. There are many documented food-borne outbreaks in people; perhaps the classic outbreak was described by Mason and McLean (1962), who identified the source of oysters harvested from polluted water. The infectious hepatitis virus has been shown to be stable during refrigerated storage of oysters. The problems is of further concern since many oysters are eaten raw.

11.4.2.11 Poliomyelitis

There are limited number of reported food-borne outbreaks of polio. Cliver (1967) noted ten such outbreaks between 1914 and 1949. Milk (both pasteurized and raw) was implicated in eight of the ten outbreaks, and the lemonade and a cream-filled pastry in the remaining two. The implication of pasteurized milk (two outbreaks) is noteworthy since the heat required for pasteurization should inactive the polio virus.

11.4.2.12 Other Viruses

The virus responsible for food and mouth disease in cattle can be transmitted to people in foods. Two viral diseases of poultry, ornithosis and Newcastle disease, have implicated in the human ailments. The ornithosis virus produces a respiratory infection in man. Other viruses which are considered good candidates for food-borne transmission are enteroviruses including coxsackie and ECHO viruses. At least eighty individuals became ill following the consumption of coleslaw in a 1976 outbreak which was attributed to ECHO virus 4. One of the most frequently involved virus in recent year has been the “Norwalk” viruses or Norwalk-like agents.

Table 3: Viruses Implicated in Food-borne Outbreaks

Illness	Causative agent	Foods usually Involved	Other modes of transmission	Incubation period	Signs and symptoms	Measure to prevent spread by food
Poliomyelitis*	Poliovirus type I, II, III	Milk; possibly other beverages and prepared foods	Case or carrier; contaminated water	5-35 days	Fever; vomiting; headache; pain in muscle groups; paralysis	Personal cleanliness; adequate heating of foods; disinfection of

						water; prevention of contact of flies with foods
Infectious hepatitis*	Infectious hepatitis virus(or viruses)	Milk and other beverages; shellfish (raw oysters and clams); specific foods served as part of a meat, such as potato salad	Case or carrier; contaminated water	10-50 days, mean 25 days	Jaundice in approximately one-half of cases; loss of appetite, gastrointestinal disturbance	Cooking of shellfish; checking personnel handling food; adequate heating of milk and foods; adequate heating or disinfection of water; cleanliness of food handlers
Acute nonbacterial gastroenteritis*	Coxsackie and ECHO viruses; viral agents as yet unidentified	Possibly food-borne, but as yet this mode of transmission is unestablished	Case or carrier	27-60 hr (average)	Fever; constitutional symptoms; head-ache; abdominal pain, vomiting, and diarrhea	Probably the same as for poliomyelitis

11.4.2.13 Significance in Foods

In addition to the known food-borne viral outbreaks there are many suspected viral implicated food-borne disease outbreaks. The lack of methodology and susceptible host cell lines complicates viral surveys of foods. It is not unreasonable to assume that the enteroviruses (intestinal viruses) can enter our food supply as readily and as frequently as the enteric bacteria, since they can be isolated from feces as readily as the coliforms and the enteric pathogens.

The rickettisias may be considered degenerative bacteria since they represent a form of life closely resembling bacteria expect that they cannot be cultivated outside of living cells. The mode of transmission of rickettsias to people is quite variable, but at some point in their normal life cycle rickettsias are associated with fleas, lice, or ticks.

Cows infected with the rickettsias of Q fever, *Coxiella burnetii*, are of public health concern, since the organism can be excreted in milk in large quantities and result in human infections. At one time the pasteurization times and temperatures for milk

11.4.3 FOOD-BORNE PARASITES

Although no attempt will be made to discuss in any detail the numerous parasitic round or flatworms, protozoa, and flukes occasionally in foods, it is important for the food microbiologist to be aware of their existence. A summary of common parasites is presented in table comprehensive listing of possible parasites transmitted in foods can be found in Table

11.4.3.1Trichinosis

Trichinosis, although caused by a nematode worm, *Trichinella spiralis*, usually is discussed along with bacterial food poisoning and infection because all have similar symptoms and all are food-borne. Most human trichinosis results from the consumption of raw or incompletely cooked pork containing the encysted larvae. The fertilized females give birth to numerous larvae, which travel through the bllod vessels and lymphatics to skeletal muscle tissue, where they encyst. The worm goes through a similar cycle in hogs, rats, and other hosts.

(a)Symptoms

The incubation period between ingestion of the pork and the first symptoms varies widely, being reported to be as short as a day or two and as long as several weeks. The first symptoms, which may be confused with food poisoning, appear when the larvae, freshly released from their cysts in the ingested and digested pork, invade the mucosa. Symptoms may include nausea, vomiting, diarrhea, profuse sweating, colic, and loss of appetite and may continue for days. Later symptoms, resulting from the migration of the newborn larvae to the muscle and their encystment there, are mostly related to muscular soreness and swelling and would not be confused with food poisoning. Death may follow in severe cases.

Table 4: Important parasitic Infections Transmitted by Foods

Illness	Causative agent	Foods usually involved	Incubation period	Signs and symptoms	Measure to prevent spread by food
anisakiasis	Anisakis spp. (a nematode)	Raw or insufficient cooked fish	Several days	Irritation of throat and digestive tract	Cook fish thoroughly
Amebic dysentery (amebiasis)	Endamoeba histlytica	Water contaminated with sewage; moist food contaminated with human feces	Several days to 4 weeks	Diarrhea of varying severity; fatalities not uncommon	Protect water supplies; cleanliness in food preparation; ensure proper disposal of human excreta
Beef tapeworm (taeniasis saginata)	Taenia saginata	Raw or insufficiently cooked beef containing live larvae	Several weeks	Abdominal pain, hungry feeling, vague discomfort	Use meat processes under veterinary inspection; cook beef thoroughly
Fish tapeworm (diphyllobothiriasis)	Diphyllobothrium latum	Raw or insufficiently cooked fish containing live larvae	3-6 weeks	Usually none; anemia in heavy infection	cook fish thoroughly; avoid eating raw smoke d fish
Pork tapeworm (taeniasis solium)	Taenia solium	Raw or insufficiently cooked	Several weeks	Varies from a mild chronic,	Use meat processed under

		pork containing live larvae		digestive disorder to severe malaise with encephalitis; may be fatal	veterinary inspection; cook pork thoroughly
Trichinosis	Trichinellaspiralis	Raw or insufficiently cooked pork and pork products; whale, seal, bear, or walrus meat containing live larvae	Usually 9 days but may vary from 2 to 28 days; in heavy infection 24 hr	Nausea, vomiting, diarrhea, muscular pains, fever, labored breathing, swelling of eyelids; occasionally fatal	Cook pork and pork products thoroughly; freeze pork at -15 C for 30 days, or at -23 C for 20 days; or -29C for 12 days; cook garbage fed to swine; eliminate rats from hog lots

Table 5: Endoparasites Transmissable through Foods

Parasites	Potential pathogenicity	Methods of infection
Protozoa		
Entamoeba histolytica	+	Food and drink contaminated with cysts
Entamoeba coli	-	Food and drink contaminated with cysts
Endolimax nana	-	Food and drink contaminated with cysts
Lodamoeba butschlii	-	Food and drink contaminated with cysts

Dientamoeba fragilis	+	Food and drink contaminated with trophozoites
Retortamonas intestinalis	-	Food and drink contaminated with cysts
Retortamonas sinensis	+	Food and drink contaminated with cysts
Chilomastix mesnili	-	Food and drink contaminated with cysts
Enteromonas hominis	-	Food and drink contaminated with cysts
Enteromonas hervei	-	Probably via food and drink contaminated with cysts
Trichomonas hominis	-	Food and drink contaminated with trophozoites
Trichomonas tenax	-	Food and drink contaminated with cysts
Giardia lamblia	+	Food and drink contaminated with cysts
Isospora belli	+	Food and drink contaminated with cysts
Isospora natalensis	+	Food and drink contaminated with cysts
Balantidium coli	+	Food and drink contaminated with cysts
Sarcocystis ssp.	+	Red meat containing cysts
Toxoplasma gondii	+	Meats and milk contaminated with cysts
Nematoda		
Trichinellaspiralis	+	Meats containing larvae
Trichuris trichiura	+	Food and drink contaminated with eggs
Capillaria hepatica	+	Food and drink contaminated with eggs
Capillaria philippinensis	+	Ingestion of fish harboring larvae
Dioctophymae renale	+	Ingestion of fish harboring larvae
Rhabditis sp.	-	Contaminated drink; mollusces
Syngamus laryngeus	-	Food and drink contaminated with larvae
Trichostrongylus sp.	+	Vegetables contaminated with larvae
Haemonchus contortus	+	Vegetables contaminated with larvae
Enterobius vermicularis	+	Food and drink contaminated with eggs

Syphacia obvelatea	-	Food and drink contaminated with eggs
Ascaris lumbricoides	+	Food and drink contaminated with eggs
Toxocara cati	+	Food and drink contaminated with eggs
Toxocara canis	+	Food and drink contaminated with eggs
Gnathostoma spinigerum	+	Fish and frog legs containing larvae
Echinocephalus sp.	+	Oysters containing larvae
Phocanema decipiens	+	Fish containing larvae
Anisakis spp.	+	Fish containing larvae
Porrocaecum sp.	+	Fish containing larvae
Contracaecum sp.	+	Fish containing larvae
Angiostrongylus cantonensis	+	Vegetables contaminated with larvae or small molluses harboring larvae; prawns and other paratenic hosts
Angiostrongylus costaricensis	+	Vegetables contaminated with slugs harboring larvae
Cestoda		
Spirometra sp. Larvae	+	Water containing procercoid infected Cyclops sp.
Diphyllobothrium latuerm	+	Fish harboring plerocercoids
Diplogonoporus grandis	+	Fish harboring plerocercoids
Diagramma brauni	-	Fish harboring plerocercoids
Ligula intestinalis	-	Fish harboring plerocercoids
Braunia jasseyensis	-	Probably fish harboring plerocercoids
Taenia solium	+	Pork containing cysticerci
Taeniarhynchus saginatus (Taenia saginata)	+	Beef containing cysticerci
Multiceps multiceps (larva)	+	Food and drink contaminated with eggs
Multiceps serialis (larva)	+	Food and drink contaminated with eggs
Echinococcus granulosus (larva)	+	Food and drink contaminated with eggs

Echinococcus multilocularis (larva)	+	Food and drink contaminated with eggs
Echinococcus vogeli (larva)	+	Food and drink contaminated with eggs
Hymenolepis nana	+	Food contaminated with eggs
Hymenolepis diminuta	+	Food contaminated with cysticercoid infected beetles
Trematode		
Watsonius watsoni	+	Vegetables contaminated with metacercariae
Gastrodiscoides hominis	+	Vegetables contaminated with metacercariae
Fasciola hepatica	+	Vegetables contaminated with metacercariae
Fasciola gigantica	+	Vegetables contaminated with metacercariae
Fasciolopsis buski	+	Vegetables contaminated with metacercariae
Echinostoma spp.	+	Molluscs harboring metacercariae
Himasthla muehlensis	+	Clams harboring metacercariae
Echinochasmus perfoliatus	+	Fish harboring metacercariae
Opisthorchis felineus	+	Fish harboring metacercariae
Clonorchis sinensis	+	Fish harboring metacercariae
Heterophyes heterophyes	+	Fish harboring metacercariae
Metagonimus yokagawai	+	Fish harboring metacercariae

(b) Diagnosis: Diagnosis often is based primarily on symptoms since other methods of diagnosis are difficult. The suspected food may be examined for encysted larvae, but they are hard to find, as are adult worms in stools of pateints.

(c) Prevention: The chief method for the prevention of trichinosis is the treatment of pork (or other meat) to ensure the destruction of any trichinae that may be present.

- The thorough cooking of all pork so every part reaches at least 58.3^0
- Quick freezing or storage at -15C or lower for not less than 20 days
- Treatment with 20,000 rep of ionizing rays (or)
- Processing sausage or similar pork products according to recommended schedules of salting, drying, smoking, and refrigeration as formulated originally by the former Bureau of animal industry of the USDA. Inspection of animals and meats for trichinae at the packing plant is

laborious and not always successful, although formerly practiced. Some attempt has been made to reduce the incidence of trichinosis in swine by control of rats and by cooking garbage fed to hogs.

11.5 NON-BACTERIAL INFECTIONS AND INTOXICATIONS

Freezing and thawing techniques as well as other food storage procedures are constantly being improved to preserve taste, but the same innovations also preserve microbes. Consumer habits may also account for the current importance of parasites as food borne pathogens, particularly the vogues for raw recipes and undercooking to savor “natural” taste and save heat-liable nutrients. It is a neglected discipline compared to food bacteriology. Methods usually have been adapted and hoc from those used for clinical specimens or soil samples.

11.5.1 Types of Animals that may be Food Borne Parasites

Many microscopic or small microscopic animals are consumed live with food and drink. Given the right circumstances, most can survive ingestion at least for short time spans. To consider all as parasites would be impractical. Some of these animals are classified as “free-living”, i.e., they normally dwell in soil or water. In contrast, parasites are defined as being tolerant of existence in or on another living organism; they may even require one host or a series of specific hosts for their survival, development, or reproduction.

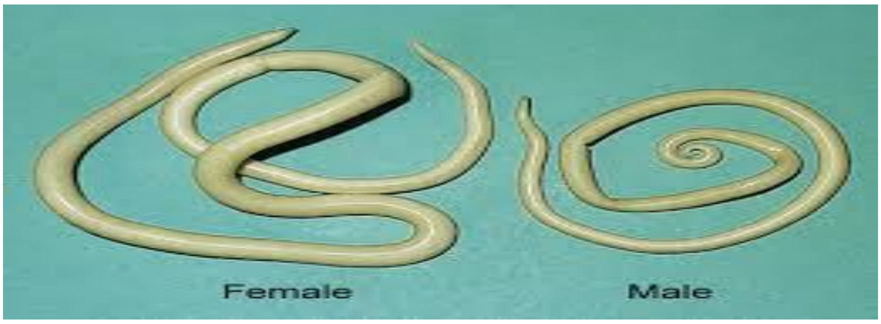


FIG. 1: *Ascaris: male and Female.*

Most of the small free-living animals and many of the facultative and obligate parasites of plant or cold blooded animal hosts that are associated with foods cause no pathology when they are ingested live by humans.

It is not exceptional to find that those parasites, which require warm blooded animals as “definitive” hosts for their sexual maturation will cause pathology when ingested live with food. Even, if like the fish borne anisakine nematodes of marine mammals, they do not mature or survive long in humans, these organisms nevertheless may be etiologic agents of disease and are commonly listed among our food borne parasities. More than 60 genera of invertebrate animals are implicated in human infection through food and drink. Included are unicells (Protozoa) and such Metazoa as tapeworms (cestodes), flukes (trematodes), roundworms (nematodes, and

insects (usually larval files). Despite the variety, relatively few species cause most of the incidents of food borne and waterborne parasitic disease in industrialized nations of the temperate zone. Survive sewage sludge is used as plant fertilizer; eggs of the pinworm, *Enterobius vericularis* from the host's perianal region may become airborne and settle onto foods or into drinks.

Infection statistics may be deceptive, however. The evidence is both incomplete and, in some cases, circumstantial. If is incomplete in so far as parasitic diseases are often undiagnosed, misdiagnosed, or unreported to health authorities. For instance, although one can assume that cases of trichinosis are caused by the ingestion of undercooked meat or meat products (containing *Trichinella spiralis* larvae), it is not safe to assume that cases of ascariasis are food borne. The infective eggs of *Ascaris* spp. May bed ingested from several different sources, only one of which is fecally contaminated food.

11.5.2 Types of Foods with which parasites are Associated

Water and fresh edibles are the principal items with which drink borne and food borne human parasites have been associated. The edibles may be of either animal or plant origin. Those plants having their consumable portions in contact with soil or water are the ones most likely to be involved if they are normally eaten unpeeled, uncooked, or undercooked. Raw and undercooked meats are also likely sources of infective stages of parasites.

11.5.3 Types of Infections Caused by Ingested Parasites

Parasites that enter the human body by way of digestive tract do not necessarily remain confined to the lumen or adjacent tissues. Ingested *T. spiralis* reproduce in the intestine, but the new generation of larvae migrates to the musculature. Ingested eggs of *Ascaris lumbricoides* hatch and release larvae, that migrates from the intestine to the liver and lungs. Then they return to the intestine where they produce eggs that are evacuated with the faces.

Species of parasites vary considerably in where they go and how they get there. Nevertheless, patterns based on host adaptation or, sometimes, on phylogenetic relationships have been discerned. Species more adapted to other hosts may "wander" two closely related liver flukes, *Opisthorchis felineus* and *Clonorchis sinensis*, migrate by way of the bile duct, but *Fasciola hepatica*, not as similar phylogenetically, migrates to the liver through the intestinal wall and abdominal cavity.

It may also useful to classify infections by the survival and reproductive potentials of the parasites in a particular host. Human infections with "intestinal" protozoa are greatly modified by the conditions of a given host's physiological resistance or immunity.

Food as we know is the main source of contamination of disease, which is main cause of spread of the microbes like *Salmonella*, *Escherichia coli* etc. foods are also the source of various other disease-causing agents such as helminthes, nematodes, protozoa and viruses as well

as toxic metabolities of fungi and algae. A food microbiologist should also be aware of the significance and occurrence as well as the disease cycle of these non-bacterial agents of food-borne illness. Here we consider each food-borne pathogen separately.

11.5.4 HELMINTHS AND NEMATODES

Microbiologists do not normally study the flatworms and roundworms but among these groups there are a number of animal parasites, which can be transmitted to humans via food and water. These complex animals cannot be detected in foods and they do not multiply and enumerated by cultural methods in the way that many bacteria can.

(a) Platyhelminths: Liver Flukes and Tapeworms

- Plathyhelminths have been divided into two main classes i.e. Trematoda, which includes the liver fluke (*Fasciola hepatica*), and the Cestoidea, which includes tapeworms of the genus *Taenia*. These organisms have complex life cycles, which may include quite unrelated hosts at different stages. Thus the mature stage of liver fluke develops in humans, sheep or cattle, which may be referred to as the definitive host.
- The eggs after hatching period give rise to motile embryo, which is ciliated and cannot infect the definitive host but infect a water snail like *Limnaea truncatula*. There are several stages of development in the lifecycle in secondary host, some leading to multiplication of the parasite, but eventually the organism is released as the larval stage (final), which encysts and may survive for up to a year depending on the environment in the host body.
- The common symptoms of this disease include, fever, tiredness and loss of appetite with pain and discomfort in the liver region of the abdomen. Such a situation is known as fascioliasis. By the presence of eggs in the faeces, they can be diagnosed.

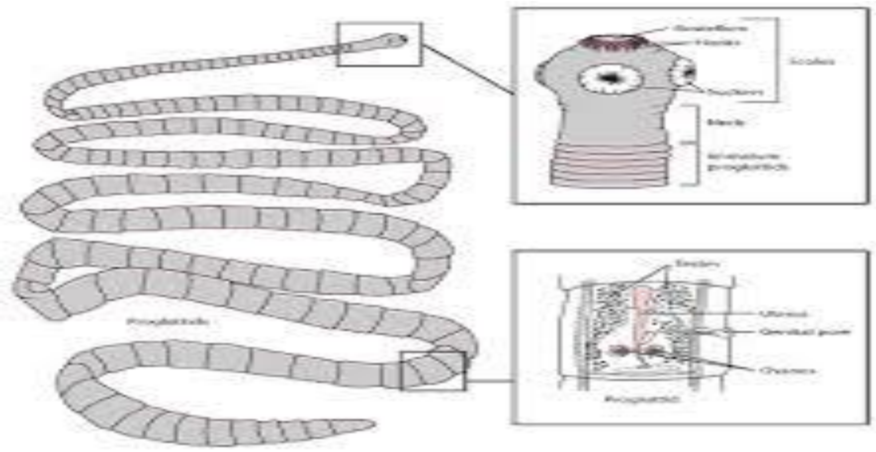


FIG. 2. Life cycle of Tape-worm

- Among the tapeworms, there are two main pathogens; that is *Taenia solium*, which is most commonly associated with the pork and the other *Taenia saginata*, associated with the beef. These are also known as flat worms or ribbon worms and their life cycle includes human as a definitive host but differ in their secondary host. However, the larval stages of *Taenia solium* can develop in humans or pigs. These larval stages, known as cysticerci, develop in a wide range of tissues including muscle tissue where symptoms can be diagnosed by the presence of spots on the body of the host.
- The mature tapeworm of these species can only develop in the human intestine where it cause more severe symptoms in the young and those weakened by other diseases, than in healthy adults. Irritation in gut may be so severe that it can cause a reversed peristalsis, so that mature segments of the tapeworms, known as proglottides enter the stomach and release egg or onchospheres, leading to an invasion of the body tissues, which is commonly known as cysticercosis.

(b) Roundworms

- Roundworms are also a very severe cause of many foods borne illness leading to many epidemics. Among the roundworms the nematodes are considered as dreaded organisms in contrast with the food borne illness. Here we basically concern with that of trichinellosis and its causal organism *Trichinella spiralis*. This parasite is passed from the host to host including a wide range of mammals like pigs and humans as well as it have no free-living stage.
- The common symptoms caused by *Trichinella* include discomfort, fever and even death as well as it has an intriguing life history for it is the active larval stages. Infection starts by the consumption of muscle tissue containing encysted larvae, which have curled up in a characteristic manner in a cyst with a calcified wall. In this stage they can survive for many years in a living host but, once eaten by a second host, the digestive juices of the stomach release the larvae and they grow and mature in the lumen of the intestines where they may reach up to its entire length and mature.

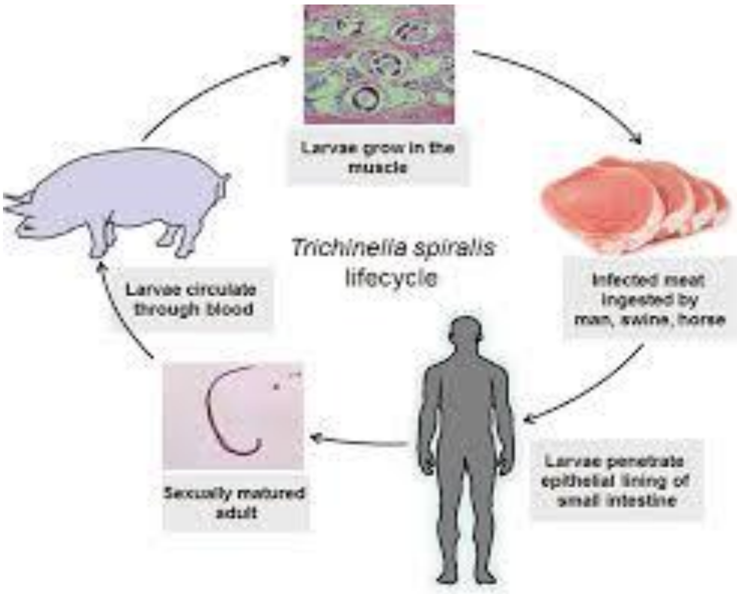


FIG.3. *Life cycle of Trichinella spiralis*

- Any apparent symptoms are not caused by the adult worms but a single female can give a large number of eggs producing more than a thousand larvae. These larvae burrow through the gut wall and eventually reach a number of specific muscle tissues in which they grow by curling up and encysting.
- The symptoms caused by *Trichinella spiralis* occur in two phases. The period during which the larvae are invading the intestinal mucosa is associated with abdominal pain, nausea and diarrhea. This may occur within a few days after eating heavily infested meat or after as long as month if only a few larval cysts are ingested. The second phase of symptoms, which include muscle pain and fever, occurs as the larvae invade and finally encyst in muscle tissue.
- For getting rid of the *trichinellosis* adequate cooking of pork products and breaking the cycle of larva within the pig population are best methods. Freezing also destroy encysted larvae but in may take as long as 30 days at-15°C.
- The control of these parasites in the human food chain is affected by careful meat inspection and the role of the professional meat inspector, Support by legislation is very important. badly infected animal maybe recognized by ante-mortem inspection and removed at that stage

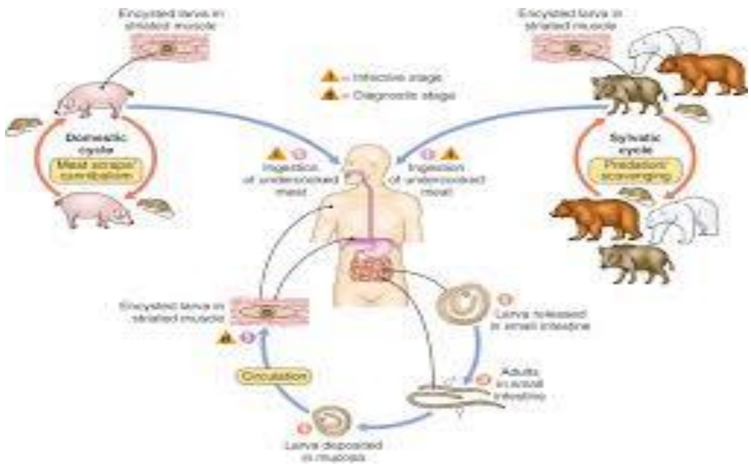


FIG. 4. *Infection cycle in man*

- For the interest of food microbiologists very few-genera belongs to the phylum protozoa that is the flagellate giardia, the amoeboid Entamoeba and three sporozoids , which are the member of the class sporozoa which contains parasitic propagated by spores.

(c) Giardia lamblia

- A number of outbreaks of the diarrhoeal disease are caused by Giardia lamblia, which may also be known as *G. intestinalis* or *lamblia intestinalis*. The organism survives in food and water as cysts but, although it can be cultured in the laboratory, it does not normally grow outside its host. The infective dose may be very low and once ingested the gastric juices aid the release of the active flagellate protozoa, known as trophozoites, which are characterized by the possession of eight flagella and two nuclei.

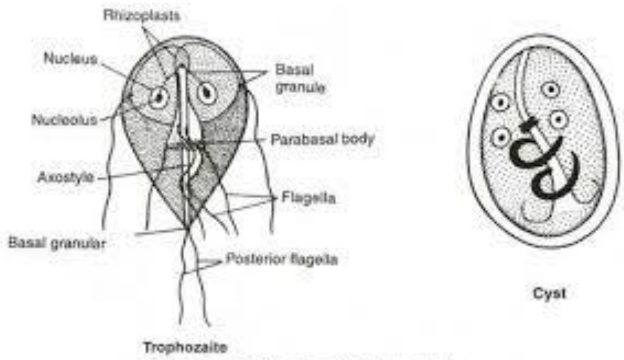


Fig. 181. Stages of life cycle of *Giardia intestinalis*.

FIG. 5. *Giardia lamblia*

- Giardia cysts are commonly present on salad vegetables like lettuce and fruits such as strawberries and also found on any foods, which are washed with contaminated water or handled by infected persons not observing good hygienic practice.
- They can be controlled by normal cooking processes of food preparations as well as they can be controlled by the chlorinated water up to an event, as it has been believed that they are resistance to chlorinated water.

(d) Entamoeba histolytica

- Amoebic dysentery is usually transmitted by the faecal-oral route and can be very widespread wherever there is poor hygienic environment. The organism is an aerotolerant anaerobe, which survives in the environment in an encysted form. A person with amoebic dysentery passes up to fifty million cysts per day. *Entamoeba histolytica* infection is endemic in many poor communities in all parts of the world.

(e) Sporozoid Protozoa

- Cryptosporidiosis appears to be an increasing cause of diarrhea and although the disease is normally self-limiting, it can become a serious infection in the immune compromised such as AIDS patients. It is very uncommon for food to be directly implicated in cryptosporidiosis but this may reflect the difficulties in detecting small numbers in food and the low infective dose required to cause disease.
- Although it complex, the whole life cycle of Cryptosporidium parvum can take place in single host, which may be man or a species of farm animal such as cattle or sheep. Two species can infect human; *S. horninis*, which infects cattle, and *S. suihominis* from pigs. Although symptoms are usually mild, they can include nausea are diarrhea. Beef and pork, which have been adequately cooked, lose their infectivity.
- In case of *Toxoplasma gondii*, the definitive host is the domestic or wild cat but many vertebrate animals including humans are susceptible to infection by the oocysts shed in their faeces. Although food-borne infection in man may be rare, it could occur through consumption of raw or under-cooked meat, especially pork or mutton. Toxoplasmosis is usually symptomless or associated with a mild influenza like illness in healthy humans, but infection can be serious in immune-compromised people.

11.5.5 TOXIGENIC ALGAE

Algae are the photosynthetic eukaryotic plants. Cyanobacteria and blue green algae are also the part of the algae and here we will consider both these as a part of algae. A number of planktonic and benthic algae can produce very toxic compounds, which may be transported to filter-feeding shellfish such as mussels and clams, or small herbivorous fish, which are food for larger carnivorous fish. In the case of shellfish, the toxins may accumulate without apparently harming the animal but with potent consequences for people or bird consuming them.

(a) Dinoflagellate Toxins

- Planktonic dinoflagellates are very commonly found forming a bloom containing a high numbers of organisms when environmental

conditions such as temperature, light and nutrients are appropriate. The toxic metabolites of these algae, which include saxitoxin and gonyautoxin block nerve transmission causing symptoms such as tingling and numbness of fingertips and lips, giddiness and staggering, incoherent speech and respiratory paralysis Saxitoxin, so named because it was isolated directly from the Alaskan butter clam, *Saxidomas giganteus*. To control paralytic shellfish poisoning, the collection nad sale of bivalves in areas affected by algal blooms is banned.

- A third quite different form of poisoning associated with eating shellfish, which have accumulated dinoflagellates is diarrhoeic shellfish poisoning caused by lipophilic toxins such as dinophysistoxin produced by *Dinophysis fortii*. The major symptoms, which usually occur within a hour or two of consuming toxic shellfish, include diarrhea, abdominal pain, nausea and vomiting and may persist for several days.
- For many years a strange type of poisoning occurring after eating a number of different species of edible fish, including moray eel and barracuda, has been known as ciguatera poisoning. Nausea, vomiting and diarrhea may be accompanied by neurosensory disturbances, convulsions, muscular paralysis and even death. It has been confirmed that the toxin responsible for these symptoms are produced by the benthic or epiphythic species of dinoflagellate known as *Gambierdiscus toxicus*.

(b) CYNOBACTERIAL TOXINS

- Several species of blue green algae and cyanobacteria especially species of *Microcystis*, *Anabaena* and *Aphanizomenon*, forms extensive blooms in lakes, ponds and reservoirs and may cause deaths of animals drinking the contaminated water. Aalthough the blue-green algae are prokaryotes, their photosynthesis during, which oxygen is liberated from water, is characteristic of that shown by the eukaryotic algae and higher plants. These produce a toxic metabolite known as cyanoginosins, which is cyclic polypeptides containing some very unusual acids and are essentially hepato toxins.

11.5.6 TOXIC DIATOMS

- Diatoms are also found associated with various outbreaks related with the food borne illness. It has been found that these diatoms produce various toxic metabolities showing glutamate antagonism in the central nervous system. The toxic metabolite so produced is basically known as domoic acid and is produced by *Nitzschia pungens*, a chain-forming diatom of the phytoplankton.

11.5.7 TOXIGENIC FUNGI

- A number of fungi are parasitic on both animals, plants, human being and other fungi, and some of these parasitic associations have become very complex and even obligate. However, it is the ability of some molds to produce toxic metabolites, known as mycotoxins,

in foods and their association with a range of human diseases, form gastro enteric conditions to cancer. Some species have been especially successful in growing at relatively low water activities, Which allows them to colonize commodities, such as cereals, which should otherwise be too dry for the growth of microorganisms.

- Frequently, when molds attack foods they do not cause the kind of putrefactive breakdown associated with some bacteria and the foods may be eaten despite being moldy and perhaps contaminated with mycotoxins.

11.5.8 Common Food Borne Molds

Most molds of importance in foods are now placed in the Fungi imperfecti group whose sex cycles are not known and most or all are thought to relate with the *Ascomycetes* group.

1. ***Alternaria:*** These mold produce septate mycelia with dark conidiophores and dark conidia. The conidia have both cross and longitudinal septa and are variously shaped. some species may produce mycotoxins.
2. ***Aspergillus:*** These molds produce upright condiophores that are simple and terminate in a globose or clavate swelling. These molds appear yellow to green to black on a large number of foods. They produce septate mycelia. Some species are field and some are storage fungi. Aspergilli may be found on cakes, fruits, vegetables, meats and other products.
3. ***Botrytis (Sclerotinia):*** The mycelium is septate and the conidia are borne or apical cells. The conidia are gray in mass and one-celled. Black irregular sclerotia are frequently produced.
4. ***Cephalosporium:*** These molds produce a septate mycelium with simple and slender or swollen conidiophores. The microspores of certain species of *Fusarium* are similar in many ways to these.
5. ***Cladosporium:*** This genus is characterized by the production of septate mycelia
with dark conidiophores variously branched near the apex of the middle portion. Conidia are dark, one or two-celled, and some are lemon shaped.
6. ***Fusarium (Gibberella):*** These molds produce an extensive mycelium that is cottony in culture with tinges of pink, purple, or yellow. The conidia are canoe shaped and borne singly or in chains.
7. ***Geotrichum (Oidium):*** These are yeast-like fungi that are usually but not always white. The mycelium is septate and reproduction occurs by fragmentation of mycelium into arthrospores. These organisms are sometimes referred to as the dairy mold since they impart flavour and aroma to many type of cheese.
8. ***Gloeosporium:*** These molds produce simple and variable length conidiophores. These conidia are hyaline, one-celled, and sometimes curved. They cause anthracnoses in plants.

9. ***Helminthosporium:*** These molds produce a light to dark mycelium in culture. Their conidiophores are short or long, septate, simple and branched.
10. ***Monilia:*** These molds produce white or gray mycelia that bear branched conidiophores. The conidia are pink or tan in mass
11. ***Mucor:*** These molds produce non-septate mycelia that give rise to conidiophores that bear columella and a sporangium at the apex. The spores are smooth, regular and borne within the sporangium.
12. ***Pencillium:*** These organisms produce septate mycelia that bear condiophores arising singularly or sometimes- in synnemata with branches near the apex to form a brush like, conidia-bearing apparatus. The conidia form of piching off from philalides. Typical colours on foods are blue to blue-green.
13. ***Rhizopus:*** These molds produce non-septate mycelia that give rise to stolons and rhizoids. The sporangiophores arise at nodes and bear columella and sporangia at the apex. The spores are borne within the sporangia and are usually black in colour.
14. ***Sporotrichum:*** These molds produce non-septate mycelia that give rise to conidiophores that bear spores near the apex. The conidia are hyaline, one-celled, globose, or ovoid, attached apically and laterally. They have been reported to grow at and below 0°C.
15. ***Thamnidium:*** These organisms produce non-septate mycelia that bear sporangiophores with large sporangia at the tip and lateral aporangioles near the base. They may be found in a large number of decaying foods such as eggs.
16. ***Trichothecium (Cephalothecium):*** These forms produce septate mycelia that bear long, slender, and simple conidiophores. The conidia appear singly, apically, and sometimes in groups of chains.
17. ***Byssocchlamys:*** members of this genus of *Ascomycetes* produce clusters of asci each of, which contain eight ascospores. The asci appear to be without a covering wall or ascocarp. The ascospores of these organisms are heat resistant, resulting in some spoilage of some high acid canned foods.
18. ***Colletotrichum:*** This genus belongs to the order Melanconiales. They produce simple but elongate conidiophores and hyaline conidia that are one-celled, ovoid, or oblong. The acervuli produced are disc or cushion shaped, waxy, and generally dark in colour.

11.5.8.1 Common Food Borne Yeasts

- ***Film yeasts:*** They grow at the surface of certain acid products such as sauerkraut and pickles. Some film yeasts are species and strains of the genera *Candida* and *Hansenula*.
- ***Top yeasts:*** They carry out the conversion of sugars to alcohol at the top of a vessel.
- ***Bottom yeasts:*** They can do the same but from the bottom of the vessel. **Apiculate** or lemon-shaped yeasts are undesirable in wine fermentations, where they produce off-flavours.
- ***Brettanomyces:*** These are acid-producing asporogenous yeasts that produce oval, elongate, spherical, or olive-shaped cells.

Reproduction is by multipolar budding that often leads to the formation of chains of cells.

- ***Candida:*** These are yeast-like organisms that are sometimes placed among Fungi imperfecti (family Moniliaceae) along with the genera *Trichothecium* and *Geotrichum*. They reproduce by either fermentation of mycelium into blastospores, or by budding.
- ***Debaryomyces:*** These are ascosporogenous yeasts that sometimes produce a pseudomycelium and reproduce multipolar budding and also by sexual means.
- ***Hansenula:*** These are ascosporogenous yeasts that produce spherical, elongate, or oval cells and often a pseudomycelium and reproduce by the multipolar budding and by sexual means.
- ***Kloeckera:*** These are nonspore-forming yeasts common on fruits where they are disseminated and also consumed by fruit flies. They possess both fermentative and oxidative abilities.
- ***Kluyveromyces (Fabospora):*** These are ascospore-forming yeasts, the ascospores are reniform to oblong with asci containing one to many spores, which are released at maturity.
- ***Mycoderma:*** These are asporogenous yeasts that usually grow on the surface of beer; pickle brines, fruit juices, vinegar and other related products and produce heavy film and pellicle.
- ***Rhodotorula:*** These are asporogenous yeasts that sometimes produce a primitive type of pseudomycelium. Reproduction is by multipolar budding. Many produce red pigments both on cultural media and on various foods.
- ***Saccharomyces:*** These are ascosporogenous yeasts that produce ovoid, spherical, or elongate cells. Reproduction is by multipolar budding and ascus formation where from one to four spores are formed. These organisms are very widespread on fruits (especially grapes) and vegetables, where they cause a fermentation of sugars leading to CO_2 and ethanol.
- ***Saccharomycopsis (Endomycopsis):*** These are ascospore forming or true yeasts that are oxidative. They are common on stored cereal grains and commonly form films on fermenting sauerkraut and cucumbers.
- ***Schizosaccharomyces:*** These are ascosporogenous yeasts that reproduce either by fission, arthrospores, or sexual means. When the latter occurs, the asci contain four to eight spores that are oval, spherical, or kidney shaped.
- ***Torulopsis (Torula):*** These are ascosporogenous yeasts that produce spherical or oval cells. They reproduce by multipolar budding and sometimes produce a primitive type of pseudomycelium.
- ***Trichosporon:*** These are non-ascospore forming oxidative yeasts found in a variety of foods including fermenting maple sap, meats, and beers. At least one species is lipolytic (T. pullulans).

11.5.8.3 Fungal Toxins (Mycotoxins) in Food Stuffs

- A very large number of molds have been demonstrated to produce toxic substances known as **mycotoxins**, which may be mutagenic carcinogenic, may display specific organ toxicity, and some are toxic by other mechanisms. About 18 mycotoxins have been recognized as carcinogens, with the **aflatoxins** being the most potent. With mycotoxins, microbial assay systems reveal an 85% level of correlation between carcinogenicity and mutagenesis.
- It was discovered in 1960 that toxins produced by molds growing on cereal grains were responsible for the deaths of thousands of young turkeys that were fed the grain. These toxic were called aflatoxins, because it was found that they had been produced by certain strains of the mould Aspergillus flovus. Other toxins produced by the moulds, including some species of *pencillium*, have also been identified and are generally called *mycotoxins.*
- Generally, foods that develop mould growth in the home should be discarded; however, solid cheeses may be trimmed of mould and the non-mouldy portion used if the cheese has been kept under refrigerator.

11.5.8.4 How Mycotoxins are formed

Mycotoxins are produced by fungi as secondary metabolities during the end of the exponential growth phase and have no apparent significance to the producing organism relative to growth or metabolism. In the case of aflatoxin synthesis, it begins at the onset of the stationary phase of growth and occurs along with that of lipid synthesis. There are three proposed primary routes of secondary metabolism in fungi (polyketide, terpenoid, and that utilizing essential amino acids); the mycotoxins are synthesized via the **polyketide route**.

(a) Aflatoxins

From the poisonous feed were isolated *Aspergillus flavus* and a toxin produced by this organism that was designed aflatoxin (*Aspergillus flavus* toxin- **Afla-toxin**). It was later determined that A. parasiticus produces aflatoxins. These compounds are highly substituted coumarins, and at least eighteen closely related toxins are known. AFL, $AFLH_1$, AFQ_1, and AFP_1 are all derived from AFB_1, AFB_2 is the 2,3-dehydro form of AFB_1; and AFG_2 is the 2,3- dihydro form of AFG_1.

(b) Production and Occurrence of Aflatoxin in Foods

Aflatoxins have been found in a wide variety of foods, including milk, beer, cocoa, rasins, soyabean meal and so on. In fermented sausage at 25℃, 160 and 420 ppm of AFG_1 were produced in10 and 18 days respectively.; and ten times more AFG_1 was found that B_1. Aflatoxins have been produced in whole-rye and whole-wheat breads, in tilsit cheese, and in apple juice at 22℃. They have been demonstrated in the upper layer of 3-month-old Cheddar cheese held at room temperature and on brick cheese at 12.8℃ by *A. parasiticus* after 1 week, but not by *A. flavus*.

(c) Relative toxicity and Mode of Action of Aflatoxins

For the expression of mutagenicity, mammalian metabolizing systems are essential for aflatoxins, especially AFB_1. Also essential in their

binding with nucleic acids, especially DNA. While nuclear DNA is normally affected, AFB_1 has been shown to bind covalently to liver mitochondrial DNA preferential to nuclear DNA. Cellular macromolecules other than nucleic acids are possible sites for aflatoxins.

11.5.8.5 Other Specified Toxins

- ***Alternaria toxins:*** Several species of *Alternaria* (including *A. citri, A. alternate, A. solani,* and *A. tenuissima*) produce toxic substances that have been found in apples, tomatoes, blueberries, and the like. The toxins produced include alternariol monimethyl ether, altenuene, tenuazonic acid and altertoxin I.
- ***Citrinin:*** Penicillium citrinum, P. viridicatum, and other fungi produce this mycotoxin. It has been recovered from polished rice, mouldy bread, country cured hams, wheat, oats, rye, and other similar products.
- ***Ochratoxins:*** The ochratoxins consist of a group of at least seven structurally related secondary metabolities of, which **ochratoxin A** (OA) is the best known and most toxic.
- ***Patulin (*Clavicin, Expansin*):*** It is produced by a large number of penicillia including *P. expansum*, *P. patulum;* by some *aspergili* (*A. clavatus, A. terreus,* and others); and by *Byssochlamys nivea* and *B. fulva*. About 32 species of Aspergillus are known infect metabolities. Mouldy malt sprouts used as feedstock resulted in the death of many cows in a dairy farm near Tokyo. The toxic metabolite is named as **altoryzine**, which causes immediate muscular paralysis.
- ***Penicillic acid:*** this mycotoxin has biological properties similar to patulin. It is produced by a large number of fungi, including many penicillia (*P. puberulum*, for example), as well as members of the *A. ochraceus* group. One of the best producers is *P. cyclopium*.
- ***Sterigmatocystin:*** These mycotoxins are structurally an biologically related to the aflatoxins and like the latter. At least eight derivatives are known. They have been found in wheat, oats, Dutch cheese, and coffee beans.
- ***Zearalenone:*** There are at least five naturally occurring zearalenones, and they are produced by *Fusarium* spp., like *F. graminearum* (formerly *F. roseum*, = *Gibberella zeae*) and *F. tricinctum*. These fungi are associated with corn. These organisms invade field corn at the silking stage, especially during heavy rainfall.

11.5.8.6 OTHER MYCOTOXICOSES

The toxins producing fungi can be categorized under four genera – *Aspergillus*, *Fusarium, Penicillium* and *Stachybotrys*. Fusarium roseum grows on barley oats, and rye. *Fusarium nivale* infects oats and toxins from this fungus are fatal to horses, which feed mainly on oats. In man it causes nausea and vomiting but is seldom fatal. When lethal doses of citrea-viridin are given to rats, motor ganglions in the spiral cord and the medulla oblongata are affected resulting in paralysis, which terminates in death.

Stachybotryuotoxicosis is the name given to the disease caused by toxins of *Stachybotrys atra*.

11.5.8.7 VIRUSES AND PRODUCTION OF TOXINS

Literature is still needed about the presence of viruses in foods.

- ∗ Viruses are obligate parasites; viruses do not grow on culture media, as do bacteria and fungi.
- ∗ The usual methods of cultivation consists of tissue culture and chick embryo techniques.
- ∗ Viruses do not replicate in foods. Their number may be expected to be low relative to bacteria, and extraction and concentration methods are necessary for their recovery.
- ∗ In laboratory the virological techniques are not practiced specially in many food microbiology laboratories.
- ∗ All viruses are of less potential interest to food microbiologist.

Still, the reports are available on the presence of viruses in foods. They are as follows:

Human intestinal viruses with high potential as food contaminants:

1. **Picornaviruses:** Polioviruses, Coxsackievirus A, Coxsackievirus B, ECHO virus 1-34, enterovirus 68-71, probably hepatitis A,
2. **Reoviruses:** Reovirus 1-3, Rotaviruses,
3. **Parvoviruses:** human gastrointestinal viruses,
4. **Papovaviruses:** Human BK and JC viruses,
5. **Adenoviruses:** Human adenovirus type 1-33,
6. **Hepatitis A virus:** There are more documented outbreaks of hepatitis A traced to foods than any other viral infection. The incubation period for infectious hepatitis ranges from 15-45 days, and lifetime immunity usually occurs after an attack. The fecal-oral route is the mode of transmission, and raw of or partially cooked shellfish from polluted waters is the most common vehicle food.
7. **Rotaviruses:** They belong to the family Reoviridae and contain double-stranded RNA. They are known to cause acute diarrhea in children with, the most susceptible age being 6 months to 1 year.

11.5.8. 8 POLIO

- The genus enterovirus is made up of small (28 nm), single-started RNA viruses, and includes poliovirus, which was at one time the only virus known to be food-borne. Polio can be transient viraemia with an incubation period of 3-5 days and characterized by headache, fever and sore throat, but in minority of cases it can progress to a second stage of persistent viraemis where the virus invades the central nervous system causing varying degrees of paralysis and even death.
- Like other enterovirus infections, poliovirus is more likely to produce an asymptomatic infection in very young children. As a result, the disease was widely feared as it became more frequent in older children and young adults where it is likely to be much more severe.
- Polio is now virtually eradicated in developed countries due to the availability of very effective live and inactivated vaccines. Previously, contaminated milk had been the principal source of

food borne polio but this route of infection had been controlled by improvements in hygiene.

11.5.8.9 HEPATITIS A AND E

- A similar story applies to another enterovirus, Hepatitis A, the cause of infectious hepatitis. The incubation period varies between two and six weeks. During this period the virus multiplies in the cell of gut epithelium before the blood to the liver carries it. In the later part of the incubation period the virus is shed in the faeces.
- Primarily it is spread by person-to-person contact but food and water-borne outbreaks to occur. Milk, fruits such as strawberries and raspberries, salad vegetables such as lettuce and shellfish are common food vehicles.
- The agent of enteric ally transmitted non-A, non-B hepatitis has now been designated hepatitis E virus and molecular biology studies indicate it is a calici-like virus. It too is transmitted by the faecal-oral route and produces illness after an incubation period of 40 days.

11.5.8.10 GASTROENTERITIS VIRUSES

- A number of different viruses have been implicated in gastroenteritis by their presence in large numbers (up to 108-1010 g^{-1}) in diarrhoeal stools. In most cases it has not proved possible to culture the viruses thus preventing their full characterization.
- Although other, better characterized, viruses such as rotavirus, calicivirus and astrovirus area also known to cause diarrhea, it is these less-well- defined agents that are responsible for most outbreaks of food borne gastroenteritis where a virus is identified.
- Studies in model systems have suggested that doses low as one cell culture infectious unit can produce infection but in polio vaccination on oral dose of 100000 infectious units is given to ensure a success rate of at least 90%.

11.5.8.11 IMPORTANT DISEASES CAUSED BY TOXINS

A serious outbreak of a disease called turkey X resulted in the death of innumerable turkeys and ducklings in Brazil and Kenya (1960). Apparently the animals did not exhibit startling external symptoms except losing weight and becoming inactive. The consumption of these over wintered grains many people become the victims of a serious and often fatal, disease called **Alimentary Toxic Aleukia** (ATA).

- Turkey X Disease: Aspergillius flavus has been identified as the causative agent for the turkey X disease. The fungus A. flavus has been found to grow on peanuts that have been harvested without adequate drying. The liver of the affected animals showed initial symptoms of enlargements, with hemorrhage followed by shrinking and hardening of the liver and formation

of hyper plastic nodules leading to jaundice and finally the death of these animals.

- Alimentary Toxic Aleukia (ATA): consumption of over wintered grains in Russia (1944) caused a serious and fatal disease called ATA. Species of *Alernaria, Cladosporium, Fusarium, Mucor* and *penicillium* were isolated from grains causing ATA. The toxic metabolities of fungi causing ATA have been named as fusaricgenin, epicladosporic acid and fagicladosporic acid. They may persist in the grains for as long as 6 to 7 years.

11.5.8.12. PRIMARY SOURCES OF MICROORGANISMS FOOD IN FOODS

Before dealing with the details of the factors influencing this microbial activity, and their significance in the safe handling of foods, it is useful to examine the possible sources of microorganisms in order to understand the ecology of contamination.

(a)Diversity of Habitat

Viable microorganisms may be found in a very wide range of habitats, from the coldest of brine ponds in the frozen wasters of Polar Regions, to the almost boiling water of hot springs. Microorganisms may occur in the acidic wastes draining away from mine workings or the alkaline waters of soda lakes.

(b) Microorganisms in the Atmosphere

Perhaps one of the most hostile environments for many microorganisms is the atmosphere. Suspended in the air, the tiny microbial propagule may be subjected to desiccation, to the damaging effects of radiant energy from the sun, and the chemical activity of elemental gaseous oxygen (O_2) to, which it will be intimately exposed.

Microorganisms from air and dust include the genera of bacteria, the eighteen genera of moulds, and many of the yeasts. *Staphylococcus* and *Salmonella* spp. May at times be found in air and dust.

(c) Airborne Bacteria

The quantitative determination of the numbers of viable microbial propagules in the atmosphere is not a simple job, requiring specialized sampling equipment, but a qualitative estimate can be obtained by simply exposing a Petri dish of an appropriate medium solidified with agar to the air for a measured period of time.

The bacterial flora can be shown to be dominated by Gram-positive rods and cocci or the pigmented colonies of micrococci or corynebacteria or the large white-to-cream coloured colonies of aerobic spore forming rods of the genus *Bacillus* or small raised, tough colonies of the filamentous bacteria belonging to *Streptomyces* or a related genus of actinomycetes.

Bacteria have no active mechanisms for becoming airborne. One group of bacteria has become particularly well adapted for air dispersal. Many actinomycetes, especially those in the genus *Streptomyces*, produce minute dry spores which survive well in the atmosphere.

(d) Airborne Fungi

The airborne fungi occur as fine dry dust particles by physical disturbance and wind. Spores of *Penicillium* and *Aspergillus* are available everywhere in this passive manner and species of these two genera are responsible for a great deal of food spoilage. *Fusarium*, produce easily wettable spores and are dispersed into the atmosphere in the tiny droplets of water. The spores of *Cladosporium* are the most common spores in the air spora. Species such as *Cladosporium herbarum* grow well at refrigeration temperatures and may form unsightly black colonies on the surface of commodities such as chilled meat.

(e) Microorganisms of Soil

The soil environment is extremely complex and different soils have their own diverse flora of bacteria, fungi, protozoa and algae. The soil is such a rich reservoir of microorganisms that it has provided many of the strains used for the industrial production of antibiotics, enzymes, amino acids, vitamins and other products used in both the pharmaceutical and food industries.

(f)Microorganisms of Water

The bacteria isolated from the waters of the open oceans often have a physiological requirement for salt, grow best at the relatively low temperatures of the oceans and are nutritionally adapted to the relatively low concentrations of available organic and nitrogenous compounds. These organisms can break down macromolecules, such as proteins, polysaccharides and lipids, and they may have doubling times as short as ten hours at refrigeration temperatures of 0-7°C. The natural microflora of the fish are the members of the Enterobacteriaceae and *Staphylococcus*, which can grow well at 30-37°C. The seas around the coasts are influenced by inputs of terrestrial and freshwater microorganisms and, perhaps more importantly, by human activities. If these waters have been contaminated with sewage there is always the risk. Severe disease such as hepatitis or typhoid fever, and milder illness such as gastroenteritis have been caused by eating contaminated oysters and mussels, which seem to be perfectly normal n taste and appearance.

Table 6: Microorganisms of Soils and Water

Bacteria	Gnerea of food-borne bacteria generally found in soils and waters may be expected in foods: Acinetobacter, Alcaligenes, Bacillus, Citrobacter, Clostridium, Corynebacterium, Enterobacter, Micrococcus, Proteus, Pseudomonas, Serratia and Streptomyces among others.
Molds	They are very widespread in nature, where they participate in the degradation of both plant and animal matter as well as cause many diseases in plants and animals. Among those that are nearly always present in soils are Aspergillus, Rhizopus, Penicillium, Trichothecium, Botrytis, Fusarium, and others.
Yeast	A large number of yeast genera are associated with plants and may therefore be expected to be found in soils. Their numbers in water are generally low.

- The fresh waters of rivers and lakes also have a complex flora of microorganisms. The presence of such organisms by actually looking for a species of bacterium, which is always present in large numbers in human faeces,is unlikely to grow in fresh water, but will survive at least as long as any pathogen. Such an organisms known as an indicator organism and the species usually chosen in temperate climates is *Escherichia coli.*
- Fungi are also present in both marine and fresh waters but they do not have the same level of significance in food microbiology as other microorganisms.
- The aquatic photosynthetic microorganisms, the cyanobacteria, or blue green algae, amongst the prokaryotes and the dinoflagellates amongst the eukaryotes, have certainly had an impact on food quality and safety.

(g)Microorganisms of plants

All plants surfaces have a natural flora of microorganism, which may be sufficiently specialized to refer as the **Phyllo plane flora**, for that of the leaf surface, and the **rhizoplane** flora for the surface of the roots. The numbers of organisms are molds (*Cladosporium* or *black yeast*, *Aureobasidium pullulans*), are frequently present.

Table 7: Microorganisms associated with Plants

Bacteria	Some bacteria those are associated more with plants than with soil are *Acetobacter, Erwinia, Flavobacterium, Kurthia, Lactobacillus, Leuconostoc, Listeria, Pediococcus, and Streptococcus.*
Molds	The most important plant borne genera those that cause the spoilage of vegetables and fruits (so called market diseases). Thegenus Saccharomyces is the most notable of the yeasts that may be found on many plant products, especially fruits. Others include the genera *Rhodotorula* and *Torula.*

(h)Microorganisms of Animal Origin

All healthy animals carry a complex microbial flora, part of, which may be very specialized and adapted to growth and survival on its host, and part of, which may be transient, reflecting the immediate interactions of the animals with its environment.

- **The Skin**

The surfaces of humans and other animals are exposed to air, soil and water and there will always be the possibility of contamination of foods and food handling equipment and surfaces with these environmental microbes by direct contact with the animal surface. Nevertheless, the micro environments of the hair follicles, sebaceous glands and a skin surface have selected a specialized flora exquisitely adapted to each environment. The microorganisms are characteristic for each species of animal and in humans. Gram-positive bacteria dominate the normal skin flora including *Staphylococcus*, *Corynebacterium* and *Propionibacterium*.

- **The Nose and Throat**

The nose and throat with the mucous membranes, which line them represent even more specialized environments and are colonized by a different group of microorganisms. *Staphylococcus aureus* is carried on the mucous membranes of the nose by a significant percentage of the human population and some strains of this species can produce a powerful toxin capable of eliciting a vomiting response.

- **Animal feeds**

Any one or all of the genera bacteria, yeasts, and molds cited earlier in this chapter may be found in animal feeds. The animal feeds are of great importance in the spread of food poisoning *Salmonella*. Organisms from this source have been shown to rapidly disseminated throughout processing plants where feeds are handled.

- **Animal Hides**

Microorganisms associated with soils; water, animal feeds, dust, and fecal matter may also found on the hides of the animals. From animal hides, these organisms may again deposited in the air, onto the hands of workers, and directly into foods.

- **Microorganisms from food utensils**

The genera of microorganisms to be found on food utensils depends upon the types of foods handled, the care of these utensils, their storage, and other factors. When utensils that are stored in the open where dust might collect should be expected to have airborne bacteria, yeasts, and molds.

Table 8:.Microorganisms from Food Handlers

Bacteria	They are specifically associated with the hands, nasal cavities, and mouth. Among these are the genera *Micrococcus* and *Staphylococcous*, the most notable of, which are *Staphylococci*, which are found on hands, arms, in nasal cavities, the mouth and other parts of the body. While the genera *Salmonella* and *Shigella* are basically intestinal forms, food handlers may deposit them onto foods and utensils if each individual does not follow sanitary practices.
Molds and Yeasts	They may be found on the hands and garments of food handlers depending upon the immediate history of each individual.

- **Microorganisms from Food Handlers**

The microflora on the hands and outer garments of food handlers generally reflects the environment and habits the individuals. This flora would normally consist of organisms found on any object handled by the individual as well as some of those picked up from dust, water, soil, etc.

11.6. Control

The problems of monitoring and control of food borne viruses are very different to those posted by bacteria. An alternative would

be to use more readily cultured viruses that are shed in the faeces, such as the vaccine polio strain, as indicator organisms for the presence of pathogenic enteric viruses. Already though, techniques based on immunoassay and nucleic acid probes with the polymerase chain reaction promise to improve both sensitivity and speed of virus detection.

An interesting approach is use coliphage, a bacteriophage, which infects the enteric bacterium *E. coli*, as a viral indicator. Coliphages do not require expensive tissue culture techniques for their enumeration since they can be detected through their ability to form plaques in a lawn culture of a suitable strain of *E. coli*.

Avoiding the fertilization of vulnerable crops with harvesting waters can control primary contamination. Secondary contamination is even harder to detect microbiologically and can only be controlled by the strict observance of good hygenic practices in the handling and preparation of foods.

11.7 QUESTIONS

1. What are some examples of foodborne diseases?
2. How widespread are foodborne diseases?
3. What is the situation regarding foodborne diseases in developed and developing countries?
4. How do foodborne diseases challenge public health security?
5. Is it beneficial to use nano technology to prevent food borne disease?

11.8 SUGGESTED READINGS

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UNIT XII – FOOD SANITATION AND SAFETY – PERSONAL HYGIENE – PERSONAL FACILITIES, WATER SUPPLIES AND SEWAGE DISPOSAL

12.1. Introduction
12.2. Objectives
12.3. Food sanitation and safety
12.4. Personal hygiene
12.5. Personal facilities
12.6. Water supplies and sewage disposal
12.7. Let Us Sum Up
12.8. Unit- End- Exercises
12.9. Answer to check your Progress
12.10. Suggested Readings

12.1. INTRODUCTION

The food safety issue faces increasing attention around the world, as it is established interdependence between food that is consumed and health. Regarding that today's trades and transportation of food have an international character, a question of food safety has become a common problem in both developed and developing countries. Governments of many countries have established new institutions, standards and methods for regulation of food safety and, also, increase investment in the control of potential hazards.

Food hygiene constitutes a basic necessity of Good Manufacturing/Agricultural Practices and the development of Hazard Analysis Critical Control Point (HACCP), as well being as a component of all GFSI-benchmarked food safety standards. Government, industry and consumers all play a role in safe sanitation and food hygiene practices. Studies have shown that an appreciable percentage of food borne illness cases can be attributed to poor sanitation and food hygiene, including poor personal hygiene and contamination of equipment and/or environments.

12.2. OBJECTIVES

After going through the unit you will be able to;

- Understand the Food sanitation and Safety.
- Describe the causes and prevention of foodborne illnesses
- To withstand the principles of Hazard Analysis Critical Control Points (HACCP)
- To make it general food-handling and storage procedures
- To provide a procedures for maintaining workplace sanitation and personal hygiene

12.3. FOOD SANITATION AND SAFETY

The term "safe food" represents different ideals to different audiences. Consumers, special interest groups, regulators, industry, and academia will have their unique descriptions based on their perspectives. Much of the information the general public receives about food safety comes through the media. For this reason, media perspectives on the safety of the food supply can influence those of the general public.

Consumers are the end users and thus are at the last link of the food supply chain from production, through processing and distribution, to retail and food service businesses. Consumers are multidimensional and multifaceted. Populations differ in age, life experiences, health, knowledge, culture, sex, political views, nutritional needs, purchasing power, media inputs, family status, occupation, and education. The effect of the interrelationships of these factors on an individual's description of "safe food" has not been established.

When educated consumers were asked by the author to define safe food, their descriptions included some key elements. Safe food means food that has been handled properly, including thorough washing of fish and poultry that will be cooked and anything to be eaten raw. Safe food means food prepared on clean and sanitized surfaces with utensils and dishes that also are cleaned and sanitized. These consumers mention the importance of hand washing by those involved in food preparation and the importance of not reusing cloths or sponges that become soiled. Common sense is a guiding principle for the educated, informed consumer.

12.3.1. DEFINITION OF FOOD SAFETY

For other consumers, the descriptions of safe food are more practical, like food that does not make a person ill. For these consumers, safe food means purchasing fresh chicken and not having the package leak or drip juice, making them wonder about the integrity of the initial seal. Consumers use their senses in their descriptions of safe food, and they feel that food that looks or smells bad should not be eaten. Surprisingly, not many consumers refer to labeling as a key component of safe food. Consumers believe they know what to do with food after it is purchased, and they assume that the safety of the food is primarily determined before it reaches their hands. Published data suggest otherwise. McDowell (1998) reported the results of on-site inspections of 106 households in 81 U.S. cities by professional auditors.

12.3.1. a. DEFINITION OF TERMS

- **Food** – Any substance whether simple, mixed or compounded that
- is used as food, drink, confectionery or condiments.
- **Safety** – is overall quality of food fit for consumption.
- **Sanitation** – is a health of being clean and conducive to health.
- **Cleanliness** – is the absence of visible soil or dirt and is not necessarily sanitized.
- **Microbiology** - the branch of biology that deals with microorganisms and their effect on other microorganisms.

- **Microorganisms** - organism of microscopic or submicroscopic
- **Food Infection** - microbial infection resulting from ingestion of contaminated foods.
- **Food Intoxication** - type of illness caused by toxins. Under favorable condition certain bacteria produce chemical compounds called toxins
- **Food Spoilage** - means the original nutritional value, texture, flavor of the food are damaged, the food become harmful to people and unsuitable to eat.
- **Foodborne Illness** – A disease carried or transmitted to people by food.

12.3.2. The importance of safe food

Food may become difficult to obtain in an emergency or following a disaster. Crops may be destroyed in the fields, animals may be drowned, food supply lines may become disrupted, and people may be forced to flee to areas where they have no access to food. Moreover, the safety of whatever food there is may be affected, resulting in a greater risk of epidemics of foodborne disease. Food safety problems vary in nature, severity and extent, and depend on the situation during the emergency or disaster. For example, during floods and hurricanes, food may become contaminated by surface water that has itself been contaminated by sewage and wastewaters. Flood waters often pick up large quantities of wastes and pathogenic bacteria from farms, sewer systems, latrines and septic tanks. The crowding of survivors after disasters may aggravate the situation, particularly if sanitary conditions are poor.

Populations of pests and stray animals, such as dogs and cats, may also increase in the aftermath of disasters. Flies and other rapidly-breeding insects may increase dramatically in numbers. People may be tempted to eat drowned animals after floods, which carries a risk. Food is especially susceptible to contamination when it is stored and prepared out of doors or in damaged homes where windows and possibly even walls are no longer intact.

Fires or explosions may result in foodstuffs becoming contaminated with dangerous chemicals or microorganisms, as well as being damaged by water. Food may be damaged by smoke, chemicals used in fire fighting, or by other chemicals originating from the accidental release or improper use of insecticides, aerosols, rodenticides and other toxic substances.

Disaster-affected people eating food from centralized kitchens that are not properly equipped or run are extremely vulnerable to outbreaks of foodborne disease. The combination of environmental contamination and improper handling of food increases the risk of epidemics of diseases such as cholera and shigellosis.

i) Food control measures

Following a disaster, an assessment should be made of its effects on the quality and safety of food. Food safety authorities should ensure that foods that have not been affected are adequately protected, are not exposed to other sources of contamination, and are not kept under conditions in which bacterial growth may occur. For example, in warehouses that have

been flooded, high humidity favours the growth of moulds and bacteria in foodstuffs. Whatever intact foods remain should be moved to a dry place, away from the walls and off the floor. The extent and type of damage to food should be assessed, and a decision made regarding the separation and reconditioning of salvageable food. Unsalvageable food should be disposed of properly, either by using it as animal feed, if appropriate, or by destroying it. In addition, before they resume their activities, food businesses should be monitored to ensure they have regained the ability to ensure food safety.

If crop fields have been contaminated by human excreta, such as following floods or damage to sewerage systems, an assessment should be carried out rapidly to assess the contamination of crops and to establish measures, such as delayed harvesting and thorough cooking, to reduce the risk of transmitting faecal pathogens. Attention is also needed when pigs or cattle graze on contaminated land, to avoid the transmission of tapeworms. If water bodies used for fishing or for harvesting water vegetables have been contaminated, assessment and analysis of risk should be undertaken to decide what special measures may be needed to prevent the spread of fish tapeworms or parasitic flukes, or of diseases such as salmonella and cholera.

ii) Salvageable and unsalvageable foods

Public health and food safety authorities may be asked to examine food and advise on its fitness for human and/or animal consumption and, whether food is salvageable or unsalvageable. Salvageable foods are those that have been damaged, but that can be rendered safe through reprocessing. Unsalvageable foods are those that are irremediably damaged by microbiological, chemical or physical contaminants, or that have been exposed to conditions making such contamination likely; they should be destroyed. The necessary precautions should be taken to ensure that all foods that have been contaminated (or are likely to have been contaminated) and that cannot be made safe by reprocessing are properly disposed of. Contamination may occur without visible signs (e.g. bottles and jars can become contaminated by seepage through crown caps and screw tops), hence the guiding principle is: if there is any doubt as to the safety of the food, it should be destroyed (New Zealand Ministry of Health, 1995).

However, food is a valuable commodity, particularly in emergencies. Faced with severe shortages, people may consume food that is unfit or not intended for human consumption. For example, in 1971–1972 in Iraq, bread prepared from seed grain treated with methyl mercury caused an outbreak of poisoning. Thousands of people were affected and several hundreds died. Any decision taken by the health authorities should therefore be based on a risk–benefit assessment: where there is a risk of a shortage, the salvaging of food should be considered, provided it does not endanger public health. In disasters and emergencies, people are likely to suffer from malnutrition as a result of food shortages, and malnourished people are more vulnerable to foodborne hazards, i.e. they may be harmed by lower doses of pathogens or toxic chemicals than healthy people. In general, foods chemically contaminated as a result of pollution, chemical spills or other secondary accidents involving toxic waste are difficult or impossible to salvage and may need to be destroyed.

12.3.3. An Approach to Food Safety

Food safety does not happen by accident. To prepare safe food, you must follow certain steps and procedures throughout the entire food preparation process. You have to think, and you have to pay attention to how you prepare food to make sure it is safe. You do this by developing a food safety plan. A good food safety plan will make sure that anything that might make someone sick is under control. A basic food safety plan uses the **HACCP** method. HACCP stands for hazard analysis critical control points. HACCP was originally developed by NASA to make sure the food on their space flights was safe to eat. HACCP is not a complicated process; it just means that you have to first identify the various steps you must take when you prepare your menu items, then look for possible sources of contamination, and then find ways to control these sources.

12.3.3. a. The HACCP approach

HACCP is an approach to food safety that is systematic and preventive. It is recommended by the Codex Alimentarius Commission, the United Nations international standards organization for food safety. HACCP is used by most countries around the world and has been in use since the 1960s. HACCP goes beyond inspecting finished food products. It helps to find, correct, and prevent hazards throughout the production process. These include physical, chemical, and biological hazards. There are seven universally accepted HACCP principles. Every country that uses HACCP follows these principles.

- **Principle 1: Hazard analysis**

  A plan is laid out to identify all possible food safety hazards that could cause a **product** to be unsafe for consumption, and the measures that can be taken to control those hazards. For example, at the cooking step of the production process, one of the identified hazards is the survival of **pathogens** due to inadequate cooking time or temperature.
- **Principle 2: Identifying critical control points**

  Critical control points are the points in the production process where an action can be taken to prevent, eliminate, or reduce a food safety hazard to an acceptable level. For example, the cooking step is considered a critical control point because control measures are necessary to deal with the hazard of pathogens surviving the cooking process.
- **Principle 3: Establishing critical limits for each critical control point**

  A **critical limit** is the limit at which a hazard is acceptable without compromising food safety. For example, critical limits at the cooking stage include specific time and temperature for cooking the product.
- **Principle 4: Establishing monitoring procedures for critical control points**

  Highly detailed monitoring activities are essential to make sure the process continues to operate safely and within the critical limits at each critical control point. For example, monitoring procedures at a

cooking critical control point could include taking the internal temperature of the product with a specialized thermometer.

- **Principle 5: Establishing corrective actions**
  Actions must be taken to bring the production process back on track if monitoring indicates that deviation from critical limits has occurred. In food production, correcting problems before end-stage production is far more effective than waiting until a product is finished to test it. For example: If the required internal temperature has not been reached, a corrective action would require that the product be cooked further. If the cooking temperature cannot be reached, another corrective action would call for the product to be held and destroyed.
- **Principle 6: Establishing verification procedures**
  Verification means applying methods, procedures, tests, sampling and other evaluations (in addition to monitoring) to determine whether a control measure at a critical control point is or has been operating as intended. Verification activities also ensure that the monitoring and the corrective actions are done according to a company's written HACCP program. For example, testing and calibrating thermometers is a verification procedure that is important to ensure accurate readings. The easiest way to test a thermometer's accuracy is by submerging the probe into a pot of boiling water. If it does not read 100˚C (212˚F) then the thermometer must be adjusted to read the correct temperature.
- **Principle 7: Record keeping**
  The company must keep records to demonstrate the effective application of the critical control points and assist with official verification (which is done in Canada by the Canadian Food Inspection Agency). Records must be established to document the monitoring and verification results as well as all information and actions taken in response to any deviations found through monitoring and verification. For example, the employee responsible for monitoring a cooking critical control point completes a cooking log sheet. This sheet includes the date, the start and finish time, the temperature, and the employee's signature. If a deviation has occurred in the production process, the responsible employee records the details in a deviation log book. For more information on current food safety regulations in Canada, see Safe Food for Canadians Regulations. Here is the original HACCP document from the Canadian Food Inspection Agency (now archived).

12.3.4. Food sanitation

It included all practices involved in protecting food from risk of contamination, harmful bacteria, poisons and foreign bodies, preventing any bacteria from multiplying to an extent which would result in an illness of consumers; and destroying any harmful bacteria in the food by thorough cooking or processing.

a. Food Safety: A Top Priority

Food safety is the responsibility in every person who is involve in food service. Serving safe food is the top priority for every food service employee.

b. Dangers of food borne illness

Individual – Food borne illness are the greatest danger to food safety. It could result to illness or diseases to an individual that would affect their overall health, work and personal lives.

- Loss of family income
- Increased insurance
- Medical expenses
- Cost of special dietary needs
- Loss of productivity, leisure and travel opportunities
- Death or funeral expense

c. **Establishment** – Food borne illness outbreak can cost an establishment thousands of pesos, it can even be the reason an establishment is forced to closed.

- Loss of customers and sales
- Loss of prestige and reputation
- Lawsuits
- Increase insurance premiums
- Lowered employee morale
- Employee absenteeism
- Increase employee turn over
- Embarrassment

d. **Types of Food Contaminants**

- Biological Contaminants
- Physical Contaminants
- Chemical Contaminant

e. **Biological Contaminant** – A microbial contaminant that may cause a food borne illness (bacteria, viruses, fungi, parasites, biological toxins)

Examples:

- Sea food toxins
- Mushroom toxins
- Clostridium Botulinum
- Salmonella bacteria

f. **Preventing Biological contaminant:**

- Purchase foods only on reputable supplier
- Do not use wild mushrooms
- Maintain good personal hygiene
- Observe proper hand washing
- Clean and sanitize equipment
- Maintain clean and sanitize facilities
- Control pests

h. **Physical Contaminant** – any foreign object that accidentally find its way into food

Examples:

- Hair
- Staple wire
- Dust

i. **Preventing Physical Contaminants:**

- Wear hair restraint

- ❖ Avoid wearing jewelry when preparing, cooking and holding foods (ring, earrings)
- ❖ Do not carry pencil or pen
- ❖ Do not wear nail polish or artificial nails when working with foods
- ❖ Clean can openers regularly
- ❖ Remove staple wire in the receiving area
- ❖ Place shields on lights

j. Preventing Chemical Contaminants:

- ❖ Teach employees how to use chemicals
- ❖ Store chemicals in original containers to prevent accidental misuse, as well as leakage into food
- ❖ Make sure labels are clearly identify chemical contents of chemical containers
- ❖ Always chemical according to chemical recommendation
- ❖ Always test sanitizing solution
- ❖ Wash hands thoroughly after working with chemicals
- ❖ Wash foods in cold running water
- ❖ Monitor pest control operator and make sure chemicals do not contaminate foods

k. Main Causes of Food Borne Illness

- ❖ Cross- Contamination
- ❖ Time-Temperature Abuse
- ❖ Poor Personal Hygiene

l. Cross Contamination - occurs when microorganisms are transferred from one surface or food to another.

The bacteria can transfer from:

Hand to food Contamination - Occurs when contaminated hands handle cooked or ready to eat foods.

- ❖ How to prevent hand to food contamination?
- ❖ Wash hands properly
- ❖ Cover cuts, sores and wounds
- ❖ Keep fingernails short, unpolished & clean
- ❖ Avoid wearing jewelry, except for plain ring

12.3.5. Causes of Foodborne Illnesses

There are many myths about foodborne illness and food poisoning. Table 1 dispels some common misconceptions about food poisoning.

Table 1. Food poisoning myths

Myth	Fact
A food with enough pathogens to make you sick will look, smell, or taste bad.	A food with enough pathogens to make you sick may look, smell, or taste good.
Really fresh food cannot make people sick.	Really fresh food can cause food poisoning if it is not properly handled.
Only dirty kitchens can make people sick.	Even clean kitchens can make people sick.
Properly cooked food can never cause food poisoning.	Food poisoning can occur even when foods are properly cooked.

a. Foodborne illnesses can be caused by any of:

- ❖ Contaminants
- ❖ Improper food handling practices
- ❖ Food allergies

Understanding each of these is critical in ensuring that food safety is maintained.

b. Food contaminants can be:

- ❖ Chemical, such as cleaning agents or pesticides
- ❖ Physical, such as hair, bandages, or glass
- ❖ Biological, such as pathogens and microbes introduced from infected workers, unsanitary work surfaces, or contaminated water

c. Biological causes of foodborne illness

- ❖ Biological contaminants are by far the greatest cause of illness. biological contaminants can be controlled or removed by effective food handling practices, so it is Many of the risks associated withcritical that the safe food handling and prevention procedures outline in the rest of the book be followed. Microbes are all around us. They are living things, often too small to be seen without a microscope.
- ❖ Many microbes are beneficial, but some can cause illness or even death. These harmful microbes are called **pathogens.** Five types of microbes include bacteria, viruses, parasites, protozoa, and fungi.
- ❖ Bacteria are present in many of the foods we eat and the body itself. Most bacteria are not harmful, and some are even very beneficial to people, but some types of bacteria are pathogenic and can cause illness. Campylobacter, E.coli, Listeria, and Salmonella are examples of pathogenic bacteria. Foods that contain these bacteria must be handled correctly and cooked appropriately.
- ❖ Parasites live in or on animals and people and cause illness when the food infected with the parasite is not cooked to a temperature high enough or frozen to a temperature cold enough to kill the parasite. Trichinella (found in pork and some game meats) and roundworms (found in raw fish) are examples of parasites found in food.Protozoa are one celled animals that may be found in water. Use of water from unsafe sources can lead to illness. Giardia lamblia is an example of protozoa that may be found in water from rivers, lakes, streams and shallow wells. Food washed in water containing Giardia lamblia that is served without any further cooking (such as salad greens) can cause illness.

d. Food Intoxication and Food Infection

Have you ever had the “24-hour flu”? Probably not, because there’s no such thing. Many people who think they have the 24-hour flu have had a foodborne illness caused by some type of pathogen. A rapid reaction is normally caused by a food intoxication. A slower reaction is normally caused by a food infection. Here’s how to tell the difference between the two:

- Food **intoxication** occurs when bacteria grow in food and produce a waste product called a toxin (poison). When the food is eaten, the toxins are immediately introduced into the body, causing a rapid reaction. Example: Staphylococcus
- Food **infection** occurs when food contains living pathogens that grow in the human intestinal tract after the food is eaten. Because the bacteria continue to multiply in the body and cause infection, the reaction will be slower. Example: Salmonella

e. Improper Food Handling Practices

The top 10 causes of foodborne illness are the following:

1. Improper cooling
2. Advance preparation
3. Infected person
4. Inadequate reheating for hot holding
5. Improper hot holding
6. Contaminated raw food or ingredient
7. Unsafe source
8. Use of leftovers
9. Cross-contamination
10. Inadequate cooking

We will be looking at this top 10 list in greater detail later in the book.

f. Food Allergies

Food allergies are specific to individuals, but can be life threatening, and can be prevented by a thorough understanding of the allergy issue, knowledge of ingredients used in the preparation of foods, including pre-prepared foods, and care in ensuring separate cooking utensils, cookware, and food preparation surfaces. Oftentimes, the smallest oversights can have serious consequences, as indicated in the example below:

A customer has indicated they have an allergy to MSG and ordered chicken strips with a sweet and sour sauce. The server tells them that the restaurant doesn't add MSG to any of its food normally, so the order should be fine. After eating the sauce, the customer experiences tingling lips and hives. In follow up, the manager discovers that the pre-prepared sweet and sour sauce served with the chicken strips contains MSG on the list of ingredients. This incident could have been prevented if the server was aware of all of the ingredients used in the dish.

12.3.6. Preventing Foodborne Illness

i. Food-handling and Storage Procedures

Proper food handling and storage can prevent most foodborne illnesses. In order for pathogens to grow in food, certain conditions must be present. By controlling the environment and conditions, even if potentially harmful bacteria are present in the unprepared or raw food, they will not be able to survive, grow, and multiply, causing illness.

There are six factors that affect bacterial growth, which can be referred to by the mnemonic **FATTOM**:

1. **F**ood
2. **A**cid
3. **T**emperature
4. **T**ime

5. **O**xygen
6. **M**oisture

Each of these factors contributes to bacterial growth in the following ways:

- **Food:** Bacteria require food to survive. For this reason, moist, protein-rich foods are good potential sources of bacterial growth.
- **Acid:** Bacteria do not grow in acidic environments. This is why acidic foods like lemon juice and vinegar do not support the growth of bacteria and can be used as preservatives
- **Temperature:** Most bacteria will grow rapidly between 4°C and 60°C (40°F and 140°F). This is referred to as the **danger zone** (see the section below for more information on the danger zone).
- **Time:** Bacteria require time to multiply. When small numbers of bacteria are present, the risk is usually low, but extended time with the right conditions will allow the bacteria to multiply and increase the risk of contamination
- **Oxygen:** There are two types of bacteria. **Aerobic bacteria** require oxygen to grow, so will not multiply in an oxygen-free environment such as a vacuum-packaged container. **Anaerobic bacteria** will only grow in oxygen-free environments. Food that has been improperly processed and then stored at room temperature can be at risk from anaerobic bacteria. A common example is a product containing harmful *Clostridium botulinum* (botulism-causing) bacteria that has been improperly processed during canning, and then is consumed without any further cooking or reheating.
- **Moisture:** Bacteria need moisture to survive and will grow rapidly in moist foods. This is why dry and salted foods are at lower risk of being hazardous.

ii. Identifying Potentially Hazardous Foods (PHFs)

Foods that have the FATTOM conditions are considered **potentially hazardous foods (PHFs).** PHFs are those foods that are considered perishable. That is, they will spoil or "go bad" if left at room temperature.

PHFs are foods that support the growth or survival of disease-causing bacteria (pathogens) or foods that may be contaminated by pathogens.

Generally, a food is a PHF if it is:

- Of animal origin such as meat, milk, eggs, fish, shellfish, poultry (or if it contains any of these products)
- Of plant origin (vegetables, beans, fruit, etc.) that has been heat-treated or cooked
- Any of the raw sprouts (bean, alfalfa, radish, etc.)
- Any cooked starch (rice, pasta, etc.)
- Any type of soya protein (soya milk, tofu, etc.)

Check your progress - 1

Notes: a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

1. What is food safety and sanitation?

2. What are the importance of food safety hygiene and sanitation in food preparation?

1. What is food safety and sanitation?

The personal cleanliness and hygiene of food preparers are critical to protecting against foodborne illness. ... If a food preparer is dirty, the risk for food contamination increases greatly

2. What is the importance of food safety hygiene and sanitation in food preparation?

A sanitation plan is important in any food service preparation area. It ensures that all surfaces are cleaned on a regular basis and reduces the risks of transferring bacteria or other pathogens from an unclean surface to clean equipment such as cutting boards or tools.

12.4. PERSONAL HYGIENE

Personal hygiene can be defined as an act of maintaining cleanliness and grooming of the external body. Maintaining good personal hygiene consists of bathing, washing your hands, brushing teeth and sporting clean clothing. Additionally, it is also about making safe and hygienic decisions when you are around others.

Regular activities 12.4.1

Personal hygiene involves those practices performed by an individual to care for one's bodily health and wellbeing through cleanliness. Motivations for personal hygiene practice include reduction of personal illness, healing from personal illness, optimal health and sense of wellbeing, social acceptance and prevention of spread of illness to others. What is considered proper personal hygiene can be cultural-specific and may change over time.

Practices that are generally considered proper hygiene include showering or bathing regularly, washing hands regularly and especially before handling food, washing scalp hair, keeping hair short or removing hair, wearing clean clothing, brushing teeth, cutting finger nails, besides other practices. Some practices are gender specific, such as by a woman during her menstruation. Toiletry bags hold body hygiene and toiletry supplies.

Anal hygiene is the practice that a person performs on the anal area of themselves after defecation. The anus and buttocks may be either washed with liquids or wiped with toilet paper or adding gel wipe[50] to toilet tissue as an alternative to wet wipes or other solid materials in order to remove remnants of feces.

People tend to develop a routine for attending to their personal hygiene needs. Other personal hygienic practices would include covering one's mouth when coughing, disposal of soiled tissues appropriately, making sure toilets are clean, and making sure food handling areas are

clean, besides other practices. Some cultures do not kiss or shake hands to reduce transmission of bacteria by contact.

Personal grooming extends personal hygiene as it pertains to the maintenance of a good personal and public appearance, which need not necessarily be hygienic. It may involve, for example, using deodorants or perfume, shaving, or combing, besides other practices.

I. Introduction to Good Hygiene Practices

Safe food originates from its source, the farm. At this stage Good Agricultural Practices (GAP) are applied to ensure food safety. Subsequent to the farm, Good Manufacturing Practices (GMP) ensure products are consistently produced and controlled according to quality standards at the various stages of processing, storage and transportation till food reaches consumers. General Principles of Food Hygiene apply to both GAP and GMP through the implementation of Good Hygiene Practices (GHP). GHP recommends a HACCP-based approach to reduce risks Good Hygiene Practices aim to implement the essential principles of food hygiene applicable throughout the food chain (including primary production through to the. final consumer), to achieve the goal of ensuring that food is safe and suitable for human consumption. This chapter illustrates the application of GHP to achieve food safety goals.

II. Hands and Skins

(Food handlers must wash their hands especially)

- After visiting the toilet
- On entering the food room, after a break and before handling any food.
- After putting on or changing a dressing
- After dealing with an ill customer or a baby’s nappy
- After handling raw food including eggs, and before handling ready – to eat food.
- After cleaning up animal faces or handling boxes contaminated by bird dropping.
- After combing or touching the hair, face, nose, mouth or ears
- After handling waste food.
- After cleaning, or handling dirty cloths, crockery .etc.
- After handling external packaging, flowers or money.

III. Hand washing

Hand hygiene is defined as hand washing or washing hands and nails with soap and water or using water less hand sanitizer. Hand hygiene is central to preventing the spread of infectious diseases in home and everyday life settings.

In situations where hand washing with soap is not an option (e.g., when in a public place with no access to wash facilities), a water less hand sanitizer such as an alcohol hand gel can be used. They can be used in addition to hand washing to minimize risks when caring for "at-risk" groups. To be effective, alcohol hand gels should contain not less than 60%v/v alcohol.

The WHO (World Health Organization) recommends hand washing with ash if soap is not available in critical situations, schools without access to soap and other difficult situations like post-emergencies where use of (clean) sand is recommended, too. Use of ash is common in rural areas of developing countries and has in experiments been shown at least as effective as soap for removing pathogens.

IV. Respiratory hygiene

Correct respiratory and hand hygiene when coughing and sneezing reduces the spread of pathogens particularly during the cold and flu season.

- Carry tissues and use them to catch coughs and sneezes
- Dispose of tissues as soon as possible
- Clean your hands by hand washing or using an alcohol hand sanitizer.

V. Food hygiene at home

Food hygiene is concerned with the hygiene practices that prevent food poisoning. The five key principles of food hygiene, according to WHO, are:

- Prevent contaminating food with mixing chemicals, spreading from people, and animals.
- Separate raw and cooked foods to prevent contaminating the cooked foods.
- Cook foods for the appropriate length of time and at the appropriate temperature to kill pathogens.
- Store food at the proper temperature.
- Use safe water and raw materials.

VI. Hygiene in the kitchen, bathroom and toilet

Routine cleaning of (hand, food, drinking water) sites and surfaces (such as toilet seats and flush handles, door and tap handles, work surfaces, bath and basin surfaces) in the kitchen, bathroom and toilet reduces the risk of spread of pathogens. The infection risk from flush toilets is not high, provided they are properly maintained, although some splashing and aerosol formation can occur during flushing, particularly when someone has diarrhea. Pathogens can survive in the scum or scale left behind on baths, showers and wash basins after washing and bathing. Water left stagnant in the pipes of showers can be contaminated with pathogens that become airborne when the shower is turned on. If a shower has not been used for some time, it should be left to run at a hot temperature for a few minutes before use.

12.4.2. Importance of Personal Hygiene

It is imperative for safe food-handling outcomes for all workers to be familiar with standard sanitation and hygiene practices. Figure 1 show the cycles of transmission of micro-organisms. One of the basic principles is to break the cycle by avoiding cross-contamination, which can be achieved by ensuring personal hygiene practices are followed.

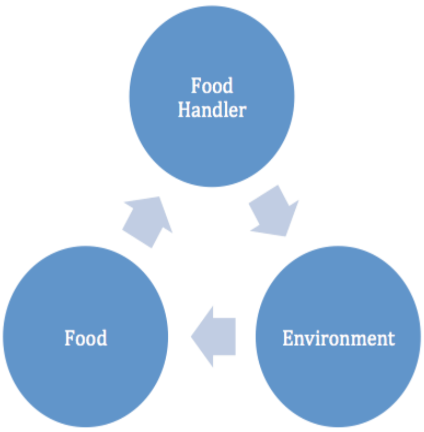


Figure 1. The cycle of bacterial transmission. Image created by go2hr and used under a CC BY 4.0 License.

1) **Proper personal hygiene is critical in any food service premise. Personal hygiene includes:**
   - ❖ Showering and bathing regularly
   - ❖ Keeping hair clean hair and covered or tied back
   - ❖ Keeping clean clothing and footwear that is used only at work
   - ❖ Hand washing regularly
   - ❖ Using clean utensils for tasting food
   - ❖ Using separate cloths for cleaning and wiping plates

2) **Hand washing**
   - ❖ Proper and regular hand washing is a critical part of any food safety system. You must always wash your hands after:
   - ❖ Sneezing, coughing, or touching your mouth or nose
   - ❖ Using the bathroom
   - ❖ Smoking or using toothpicks
   - ❖ Handling raw foods
   - ❖ Cleaning and wiping tables, food preparation surfaces, or equipment
   - ❖ Handling soiled objects, garbage, or money

12.4.3. The steps for proper hand washing are as follows:
- ❖ Wet hands with warm water.
- ❖ Apply liquid soap and lather for at least 20 to 30 seconds.
- ❖ Scrub backs of hands, wrists, all fingers, and under nails.
- ❖ Rinse under running water, pointing down toward the drain.
- ❖ Dry with a paper towel.
- ❖ Turn off taps and open bathroom door using the paper towel.
- ❖ Wet your hands with clean, running water (warm or cold), turn of the tap, and apply soap.

12.4.4. What should you do if you don’t have soap and clean, running water?

Washing hands with soap and water is the best way to reduce the number of germs on them in most situations. If soap and water are not available, use an alcohol-based hand sanitizer that contains at least 60% alcohol. Alcohol-based hand sanitizers can quickly reduce the number of germs on hands in some situations, but sanitizers do not eliminate all types of germs and might not remove harmful chemicals.

12.4.5. Hand sanitizers are not as effective when hands are visibly dirty or greasy.

a. How do you use hand sanitizers?
- ❖ Apply the product to the palm of one hand (read the label to learn the correct amount).
- ❖ Rub your hands together.
- ❖ Rub the product over all surfaces of your hands and

b. When should you wash your hands?

- Before, during, and after preparing food
- Before eating food
- Before and after caring for someone who is sick
- Before and after treating a cut or wound
- After using the toilet
- After changing diapers or cleaning up a child who has used the toilet

c. Hygiene

Hygiene is especially important in an emergency such as a flood, hurricane, or earthquake, but finding clean, safe running water can sometimes be difficult. The following information will help to ensure good hygiene in the event of an emergency.

d. Bathing

Bathing or showering after a water-related emergency should only be done with clean, safe water. Sometimes water that is not safe to drink can be used for bathing, but be careful not to swallow any water or get it in your eyes. Do not bathe in water that may be contaminated with sewage or toxic chemicals. This includes rivers, streams, or lakes that are contaminated by good water. If you have a drinking water well, listen to your local health authorities for advice on using your well water for showering and bathing. If extensive flooding has occurred or you suspect that you well may be contaminated, contact your local, state, or tribal health department for specific advice on well testing and disinfection

e. Dental Hygiene

Brushing your teeth after a water-related emergency should only be done with clean, safe water. Listen to local authorities to find out if tap water is safe to use. Visit Making Water Safe in an Emergency for more information about making your water safe for brushing your teeth.

f .Wound Care

Keeping wounds clean and covered is crucial during an emergency. Open wounds and rashes exposed to flood water can become infected. To protect yourself and your family:

- Avoid contact with flood waters if you have an open wound.
- Cover clean, open wounds with a waterproof bandage to reduce chance of infection.
- Keep open wounds as clean as possible by washing well with soap and clean water.

g. Diapering

In emergency situations, making sure that diaper changing practices remain hygienic is essential to reducing the spread of germs. Even a microscopic amount of fecal matter can contain millions of germs. CDC has developed guidelines and checklists to help parents, childcare providers, emergency responders, and others learn how to practice safe and germ-free diaper changing in emergency situations.

Check your progress - 2

Notes: a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

3. What should you do if you don’t have soap and clean, running water?

4. How do you use hand sanitizers?

3. What should you do if you don't have soap and clean, running water?

Washing hands with soap and water is the best way to reduce the number of germs on them in most situations. If soap and water are not available, use an alcohol-based hand sanitizer that contains at least 60% alcohol. Alcohol-based hand sanitizers can quickly reduce the number of germs on hands in some situations, but sanitizers do not eliminate all types of germs and might not remove harmful chemicals.

4. How do you use hand sanitizers?

- ❖ Apply the product to the palm of one hand (read the label to learn the correct amount).
- ❖ Rub your hands together.
- ❖ Rub the product over all surfaces of your hands and

12.5. SANITATION, EQUIPMENT PLAN, PLANT CONSTRUCTIONS, PERSONAL FACILITIES

Sanitation refers to public health conditions related to clean drinking water and adequate treatment and disposal of human excreta and sewage. Preventing human contact with feces is part of sanitation, as is hand washing with soap.

12.5.1. Definition

Sanitation means the prevention of human contact with wastes, for hygienic purposes. It also means promoting health through the prevention of human contact with the hazards associated with the lack of healthy food, clean water and healthful housing, the control of **vectors** (living organisms that transmit diseases), and a clean environment. It focuses on management of waste produced by human activities.

12.5.2. What is sanitation?

The word sanitation is derived from the Latin word sanitas, meaning "health." Applied to the food industry, sanitation is "the creation and maintenance of hygienic and healthful conditions." It is the application of a science to provide wholesome food processed, prepared, merchandised, and sold in a clean environment by healthy workers; to prevent contamination with microorganisms that cause foodborne illness; and to minimize the proliferation of food spoilage microorganisms. Effective sanitation refers to all the procedures that help accomplish these goals.

12.5.3. Workplace Sanitation

Maintaining a clean work environment is critical in preventing food borne illness. Bacteria can grow on unsanitary surfaces and then contaminate food. Just because a work surface looks clean does not mean

that it is sanitary. Always ensure that you clean and sanitize a work area before starting to prepare food.

12.5.4. Sanitation Equipment Implementation

After the appropriate equipment has been recommended and acquired, the vendor or a designated expert should supervise the installation and startup of the new operation. Personnel training should be provided by the vendor or by the organization responsible for manufacture of the system. After startup, regular inspections and reviews should be conducted jointly with the organization performing the sanitation study and a management team designated by the food company. In addition to daily inspections, reviews should be conducted every 6 months.

12.5.5. There are different types of sanitation relating to particular situations, such as:

- **Basic sanitation**:

Refers to the management of human faeces at the household level. It means access to a toilet or latrine.

- **Onsite sanitation**:

The collection and treatment of waste at the place where it is deposited.

- **Food sanitation**:

Refers to the hygienic measures for ensuring food safety. Food hygiene is similar to food sanitation.

- **Housing sanitation**:

Refers to safeguarding the home environment (the dwelling and its immediate environment).

- **Environmental sanitation**:

The control of environmental factors that form links in disease transmission. This category includes solid waste management, water and wastewater treatment, industrial waste treatment and noise and pollution control.

- **Ecological sanitation:**

The concept of recycling the nutrients from human and animal wastes to the environment.

12.5.6. Cleaning Procedures and Schedules

Cleaning with soap and other detergents is just one step of the cleaning procedure. It is also necessary to sanitize. Cleaning will remove any dirt or grease, but will not necessarily kill any bacteria or other pathogens. Only a sanitizer will kill bacteria and ensure the area is safe for food preparation. Leading sanitizers used in the foodservice industry are chlorine solutions (bleach), quaternary solutions (quats), and iodine. Use these materials according to the manufacturer’s instructions that accompany the product and that are found on the material safety data sheet (MSDS) using the appropriate personal protective equipment.

1. A list of cleaning and sanitizing agents or supplies with instructions on their safe use and storage
2. A cleaning schedule, outlining how each item needs to be cleaned, who is responsible, and how frequently it happens.

12.5.7. Cleaning Equipment

Cleaning is generally accomplished by manual labour with basic supplies and equipment or by the use of mechanized equipment that applies the cleaning medium (usually water), cleaning compound, and sanitizer. The cleaning crew should be provided with the tools and equipment needed to accomplish the cleanup with minimal effort and time. Storage space should be provided for chemicals, tools, and portable equipment.

a. Mechanical Abrasives

Although abrasives such as steel, wool, and copper chore balls, can effectively remove the soil when manual labour is used, these cleaning aids should not be used on any surface that has direct contact with food. Small pieces of these scouring pads may become embedded in the construction material of the equipment and cause pit corrosion (especially on stainless steel) or may be picked up by the food, resulting in consumer complaints and even consumer damage suits. Wiping cloths should not be used as a substitute for abrasives or for general purposes because they spread moulds and bacteria. If clothes are necessary, they should be boiled and sanitized before use.

b. Water Hoses

Hoses should be long enough to reach all areas to be cleaned but should be no longer than required. For rapid and effective cleanup, it is important to have hoses equipped with nozzles designed to produce a spray that will cover the areas being cleaned. Nozzles with rapid-type connectors should be provided for each hose. Fan-type nozzles give better coverage for large surfaces in a minimum amount of time. Debris lodged in deep cracks or crevices is dislodged most effectively through small, straight jets. Bent type nozzles are beneficial for cleaning, around and under equipment. For a combination of washing and brushing, a spray head brush is needed. Cleanup hoses, unless connected to steam lines, should have an automatic shutoff valve on the operator’s end to conserve water, reduce splashing, and facilitate the exchange of nozzles. Hoses should be removed from food production areas after cleanup, and it is necessary to clean, sanitize, and store them on hooks off of the floor. This precaution is especially important in the control of Listeria monocytogenes.

c. Brushes

Brushes used for manual or mechanical cleaning should fit the contour of the surface being cleaned. Those equipped with spray heads between the bristles are satisfactory for cleaning screens and other surfaces in small operations where a combination of water spray and brushing is necessary. Bristles should be as harsh as possible without creating surface damage. Rotary hydraulic and power-driven brushes for cleaning pipes aid in cleaning lines that transport liquids and heat exchanger tubes. Brushes are manufactured from a variety of materials—horse-hair, hog bristles, fibre, and nylon—but are usually nylon. Bassine, a coarse-textured fibre, is suitable for heavy-duty scrubbing. Palmetto fibre brushes are less coarse and are effective for scrubbing with medium soil, such as metal equipment and walls. Tampico brushes are fine fibered and well adapted for cleaning light soil that requires only gentle brushing pressure. All nylon brushes have strong and flexible fibres that are uniform in diameter, durable, and

do not absorb water. Most power-driven brushes are equipped with nylon bristles. Brushes made of absorbent materials should not be used.

d. Scrapers, Sponges, and Squeegees

Sometimes scrapers are needed to remove tenacious deposits, especially in small operations. Sponges and squeegees are most effectively used for cleaning product storage tanks when the operation has an insufficient volume to justify mechanized cleaning.

e. High-Pressure Water Pumps

High-pressure water pumps may be portable or stationary, depending on the volume and needs of the individual plant. Portable units are usually smaller than centralized installations. The capacity of portable units is from 40 to 75 L/minute, with operating pressures of up to 41.5 kg/cm2. Portable units may include solution tanks for mixing of cleaning compounds and sanitizers. Stationary units have capacities ranging from 55 to 475 L/min. Piston-type pumps deliver up to 300 L/min, and multistage turbines have capacities of up to 475 L/min, with operating pressures of up to 61.5 kg/cm2. The capacity and pressure of these units vary from one manufacturer to another. In a centralized unit, the high-pressure water is piped throughout the plant, and outlets are placed for convenient access to areas to be cleaned. The pipes, fittings, and hoses must be capable of withstanding the water pressure, and all of the equipment should be made of corrosion-resistant materials. **Low-Pressure, High-Temperature**

1. Spray Units

This equipment may be portable or stationary. The portable units generally consist of a lightweight hose, adjustable nozzles,steam-heated detergent tank, and pump. Operating pressures are generally less than 35 kg/cm2. Stationary units may operate at the main hot water supply pressure or may use a pump. These units are used because no free steam or environment fogging is present, splashing during the cleaning operation is minimal, soaking operations are impractical and hand brushing is difficult and time-consuming, and the detergent stream is easily directed onto the soiled surface.

2. High-Pressure Hot-Water Units

This equipment utilizes steam at 3.5 to 8.5 kg/cm2 and unheated water at any pressure above 1 kg/cm2. These units convert the high-velocity energy of steam into pressure in the delivery line. The cleaning compound is simultaneously drawn from the tank and mixed in desired proportions with hot water. The pressure at the nozzle is a function of the steam pressure in the line; for example, at 40 kg of steam pressure, the jet pressure is approximately 14 kg/cm2. This equipment is easy to operate and maintain but has the same inefficiency as the high-pressure, high volume water pumps.

3. Steam Guns

Various brands of steam guns are available that mix steam with water and/or cleaning compounds by aspiration. The most satisfactory units are those that use sufficient water and are properly adjusted to prevent a steam fog around the nozzle. Although this equipment has applications, it is a high energy-consuming method of cleaning. It also reduces safety through fog formation and increases moisture condensation, sometimes resulting in mould growth on walls and ceilings, and increased the potential for the growth of *L. monocytogenes*. High-pressure, low-

volume equipment is generally as effective as steam guns if appropriate cleaning compounds are incorporated.

4. High-Pressure Steam

High-pressure steam may be used to remove certain debris and to blow water off processing equipment after it has been cleaned. Generally, this is not an effective method of cleaning because of fogging and condensation, and it does not sanitize the cleaned area. Nozzles for high-pressure steam and other high-pressure, high-volume equipment should be quickly interchangeable and have a maximum capacity below that of the pump. An orifice of approximately 3.5 mm is considered satisfactory for an operating pressure of approximately 28 kg/cm2.

5. Hot-Water Wash

This technique should be considered a method instead of a kind of equipment or a cleaning system. Because only a hose, nozzle, and hot water are required, this method of cleaning is frequently used. Sugars, certain other carbohydrates, and monovalent compounds are relatively soluble in water and can be cleaned more effectively with water than can fats and proteins. Investment and maintenance costs are low, but the hot-water wash is not considered a satisfactory cleaning method. Although hot water can loosen and melt fat deposits, proteins are denatured; removal from the surface to be cleaned is complicated because these coagulated deposits are more tightly bound to the surface. Without high pressure, penetration of areas of poor accessibility is difficult, and labour is increased if a cleaning compound is not applied. As with the other equipment that uses hot water, this method increases both energy costs and condensation.

12.5.8. Sanitary Construction Considerations

i. Site Selection

Walsh and Walker (1990) suggested that sites should exhibit the following hygienic characteristics:

- Nearly level to a slight slope with adequate drainage
- Free of springs or water accumulation
- Accessible to municipal services (sewage, police, and fire)
- Remote from incinerators, sewage treatment plants, and other sources of noxious odours, or pests

ii. Exterior Design

The exterior should incorporate smooth, tight, walls impervious to water, and free of ledges and overhangs that could harbour birds. They should also contain sanitary seals against rodents and insects. Driveways should be paved and free of vegetation, trash, and water accumulation areas. Regular sweeping should be conducted to keep dust from blowing into storage areas.

iii. Interior Design

a. Walls and Framing

Exposed structural members may be satisfactory in non-product areas, as long as they can be kept clean and dust-free. Reinforced concrete construction is preferred for product areas, and interior columns should be kept to a minimum. Personnel doors should be fitted using self-closing devices (hydraulic or spring hinges) and screened. Gaps at door bases

should not exceed 0.6 cm, and 20-mesh (minimum) screening should be incorporated. Walls should be free of cracks and crevices, and impervious to water and other liquids to permit easy and effective cleaning. Wall finishes should consist of food approved materials, as dictated by the function of each area.

Ceilings

The use of suspended ceilings is satisfactory in nonfood areas if the space above the ceiling can be inspected and kept free of pests, dust, and other debris. Ceiling panels must be sealed into the grid but be easily removable. This feature is difficult to accomplish with most designs. Suspended ceilings are not recommended in food production or handling areas. They can become a shelter for pests and may become mouldy if wet, thus providing a source of contamination. In flour handling areas of bakeries, dust may accumulate above the ceiling very rapidly, leading to insect, microbial, fire, and even explosion hazards.

b. Sanitary Considerations

Sanitation features that are integrated into plant design were given increased emphasis by the FDA's promulgation of Good Manufacturing Practices (GMPs).

For low-moisture food products, current (CGMPs) as they relate to the design and construction should:

- Provide adequate space for equipment installation and storage of materials.
- Provide separation of operations that might contaminate food.
- Provide adequate lighting.
- Provide adequate ventilation.
- Provide protection against pests.

12.5.9. Disparities in Provision of Wash in Health Care Facilities

Further analyses were conducted on a subset of available datasets to explore disparities in provision of WASH in health care facilities within countries. Large variations were observed at the sub-national level, by settings and by type of health care facility within the same country, with smaller facilities in rural areas having disproportionally fewer WASH services compared to larger facilities (e.g. hospitals) in urban areas. For example, in Sierra Leone, access to water was higher in hospitals (87%) than in primary health care facilities (61%). Similar findings were observed in Kenya where 58% of hospitals had access to water compared to 35% in primary health care clinics. More country data sets are needed before global conclusions can be drawn, but these examples indicate a trend that larger facilities are more likely to have WASH services commensurate with their needs compared to smaller facilities. It is often these smaller, lesser serviced health care facilities which offer care to the most impoverished and vulnerable populations (WHO, 2008).

Similar observations were made at the sub-national level. In Kenya, for example, national-level coverage of water in health care facilities was 46%, but analysis by province revealed important differences ranging from coverage of 75% (Central province) to 22% (Nyanza Province). In Ethiopia, while 99% of health care facilities in the capital city of Addis Ababa provided access to water, only 23% of health care facilities in the Gambela region did (Ethiopian Ministry of Water and Energy,

2012). Unfortunately, there are insufficient data to provide similar analyses of sanitation or hygiene.

12.5.9. Water Quality Standards

Water is the underlying link which connects the various fishing activities together, such as harvesting, storing and icing onboard, handling inside a harbour and eventual sale to consumers. Assuming that fish is generally caught offshore in relatively pollution-free waters, potable water, and hence ice, come into contact with it all the way down the process in port, right up to the fish vendor's market stall. Generally speaking, most fishing harbours are connected to an approved mains supply: in some developing countries, however, the water is supplied from local resources such as lakes, rivers or underground aquifers which may or may not be contaminated. This fact alone makes it vitally important for a fishing harbour planner to understand water quality standards, the types of pollutants which may be present in the water supply and the most likely sources for these pollutants.

Also, due to the acute shortage of potable water in and around some fishing harbours in many developing countries, raw seawater (i.e. drawn from within the harbour basin) often replaces freshwater in the shore-based activities, implying that, in addition to freshwater, harbour basin or estuary waters has also to be tested for contaminants.

Contamination of water by physical and bacteriological agents may be evaluated by laboratory tests. Test results are usually expressed in parts per million (milligrams per litre or simply ppm) or parts per billion (micrograms per litre or ppb) for physical parameters and bacterial counts per 100 millilitres for organisms. For both types of contaminants, maximum levels are usually stipulated and these levels may differ from country to country. The major contaminants of concern in potable water supplies are:

- suspended solids;
- biodegradable organics (proteins, carbohydrates and fats);
- pathogens;
- nutrients (nitrogen, phosphorus and carbon); priority pollutants (highly toxic chemicals);
- Refractory organics (pesticides, phenols, surfactants);\
- heavy metals; and
- dissolved inorganic (nuisance chemicals)

a. Sanitary fittings

Toilets should be constructed to the highest standards possible to ensure the maximum lifetime. Poorly built facilities break down very quickly and generally lead to "toilets of opportunity" elsewhere around the port. Toilet facilities should always be properly maintained and full-time manning by attendants is desirable. Toilets should never open on to a work area where fish is being handled due to the risk of flooding from blocked

drains. The standard of personal hygiene of the workers employed inside the fishing port depends on the quality of the facilities provided. In many developing countries, the major reason for the breakdown is not vandalism but incorrect design and specification of the fittings at the design stage, followed by a total lack of supervision during construction and poor operational management and maintenance. The three most common fittings likely to break down prematurely under current design practices are:

- water taps;
- toilet flush systems; and
- shower heads

b. Sewage Treatment

The sewage effluent or wastewater from a fisheries harbour typically consists of three major biologically degradable constituents:

Type 1 – effluent from the toilets, faecal matter in water (typically low-volume discharge);

Type 2 – effluent from the wash hand basins and showers, soapy water (detergents present, also low-volume discharge); and

Type 3 – effluent from the fish cleaning operations, fish blood, scales and fish solids, high-volume discharge. The combined effluent from a fishing harbour should ideally be connected to a municipal sewer to be taken away and treated with normal household sewage.

If such a sewer is not available within a reasonably economic distance, then the effluent has to be treated before being discharged into a watercourse. Depending on the size of the fishing harbour, the effluent may be treated either via septic tanks and on-site natural treatment systems (artisanal harbours only) or via a proper sewage treatment plant (coastal, offshore and distant-water harbours). In both cases, adequate space should be provided for the purpose.

c. Port Wastes

Apart from sewage, a port's waste stream consists of five different types of wastes which may be broadly classified as toxic and non-toxic. The toxic wastes are:

- batteries;
- spent engine oil and bilge water oil; and
- Contaminated spares and consumables.

d. The non-toxic wastes are:

- plastic consumables and dunnage, including nets; and
- Wet fish wastes.

e. Batteries

Rechargeable lead-acid batteries contain plates of lead immersed in sulphuric acid inside a plastic case. Lead-acid batteries are recyclable and most suppliers take spent batteries back for industrial reprocessing. Sunlight may decompose the plastic casing, so proper on-site storage of

spent batteries is required to prevent the highly toxic contents from spilling out.

f. Spent oil

Oily wastes discharged to reception facilities are usually mixtures of oil, water and, in some cases, solids. The composition ratio of these solids can differ considerably, depending on the type of wastes. Waste oil and fuel residues consist mainly of oil contaminated with water, whereas bilge water consists mainly of water contaminated with oil. Waste oil maybe 100 per cent recycled and in many countries, it is now mandatory to collect used oil from different sources for recycling. Reception facilities for used engine oil inside harbours are intended as temporary storage only, whereas the reception facilities for bilge water need to separate the oil from the considerably larger volume of water. This oil can then be transferred to the used oil storage facilities for collection at a later date and the treated water returned back to the sea.

g. Bilgewater separation

Oily bilge water is normally found on inboard motorized fishing vessels and consists of engine oil (leaked out from the engine) mixed with seawater (leaked into the vessel from various sources including around the propeller shaft of many vessels), and if left standing still long enough, the oil fraction separates from the seawater and coalesces on the surface. Bilge water should not be dumped overboard but collected at the port for separation and eventual recycling of the oil fraction. The separated seawater may be returned to the sea. Both artisanal and commercial separators are available. Many of the larger fishing vessels are equipped with oily water separators; the oil being returned to a holding tank and the water pumped overboard. If the oil (often a mixture of lubricating oil and fuel oil) cannot be clarified and purified on board (for further use) it has to be discharged ashore when in port for treatment. shows a modern vertical oil coalescer.

h. Solid waste bins

Non-toxic solid waste comprises all kinds of bulky items such as old tyre fenders, pieces of rope and netting, broken fish boxes, etc. The equipment for handling this waste should facilitate the reception, segregation and temporary storage. Part of this waste may be recycled. However, the actual processing should not take place inside the port. Disposal of this waste may be handled by municipal waste services. Toxic solid waste comprises normal batteries, oil filters, engine spares, oil and paint cans, solvents, oily rags, etc. None of this waste is normally recycled and this waste is not normally handled by municipal services. This waste must not be sent to a municipal landfill but must be disposed of in a hazardous waste landfill.

The receptacle capacity should match the demand, both in terms of size and number of receptacles that are required and space availability.

Small receptacles such as barrels of oil drums are not suitable for bulky items. Household garbage from neighbourhood communities should not be dumped inside the port facilities. In practice, it may be found that both open top and closed containers are needed, especially in areas where the wind is very strong and where common garbage is generated inside the port and cannot be stored in open-top skips due to the presence of pets (cats and dogs)

i. Wet waste bins

In theory, fish should be cleaned and gutted onboard the fishing vessels on their journey back to port and dumped out at sea where it provides food for other fish. In practice, however, much cleaning and gutting still go on inside harbours and it is well worth installing reception facilities for the collection and eventual disposal of wet wastes. Irrespective of the size of the harbour, the best receptacle to use is an airtight PVC drum. These airtight containers should be placed at vantage points all around the fish handling areas. They should be placed in cool sheltered spots away from direct sunlight to avoid rapid decomposition of the fish. The disposal methods for wet wastes are various and all appear to produce the desired result, i.e. removal of wastes which may attract pests or vermin. The following methods are practised in various countries:

- burial of limited quantities to produce fertilizer;
- reloading on designated vessels for offshore dumping (a minor fee is levied on the landings to pay for this service), and
- privatizing the service via a concessionary agreement with an animal feed cottage industry Flotsam collection and disposal
- Whether a fishing port is located inside a river mouth or on the open coastline, flotsam inevitably finds its way into the harbour area. This floating debris may consist of: natural flotsam such as branches, logs, seaweed, etc.; and

12.5.10. Food Safety Guidelines for Waste Storage & Disposal in the Food Units

- To keep foods and beverages safe, it is important that you manage your waste according to regulations set by FSSAI. These guidelines (Schedule 4) ensure that waste does not come in contact with food, either directly or indirectly, through flies and insects or through more serious contaminants like effluents. Cross contamination from flies and insects that have come in contact with waste and effluents could carry bacteria to the food from the waste.

1. Disposal of Food Waste (in Food Areas)

- Remove food waste and other waste materials from the areas where the food is being handled cooked or manufactured in a routine manner
- Provide refuse or dustbin of adequate size and with a cover in the premises for collection of waste. A bin should have a mechanism for opening it without having to touch it
- Have the dustbin emptied and washed daily with disinfectant and dried before next use

- Separate liquid and solid waste at the time of placing them in the bins
- Locate your garbage cans in such a manner that it does not lead to contamination of the

1. food process
2. food storage area
3. the environment inside and outside your premises

- Keep all waste in covered containers, get it removed at regular intervals as per local law
- Internal garbage bins should be all collected together daily at an assigned collection point where they can be emptied into a public garbage collection system
- Place the bins in a sufficient distance to prevent contamination
- Dispose of food waste in such a way that it does not attract dogs, cats, birds, rodents and flies. Garbage cans must have covers
- Follow the rules and regulations including those for plastics and other non-environment friendly materials

2. Storage of Waste and Inedible Material

- Provide enough storage facility for storing of waste and inedible material prior to removable from the premises
- Ensure there is no pest and rodent access to waste of inedible material
- Ensure that stored and inedible material does not contaminate
    a) potable water
    b) equipment used for food preparation
    c) or building/premises

3. Effluent and Waste Disposal (Especially for Meat Processing Units)

- Have an efficient effluent and waste disposal system in your meat processing unit
- The effluent lines including sewer system must be constructed in such a way that they
    1. are able to carry large peak loads
    2. must not contaminate potable water lines
    3. have a biological oxygen demand of less than 1500
- Install an effluent treatment plant if necessary to dispose of effluents like gases, liquids and solids in conformity with Factory/Environment Pollution Control Board

Based on the comments & suggestions received, Food Safety Helpline would like to suggest the following:

- There should be an arrangement of separation of the biodegradable and non-biodegradable waste before placing in separate bins
- Mark waste trolleys and bins with defining symbols or have different colours for biodegradable and non-biodegradable waste/refuse bins.

4. Top 10 Rules for Waste Disposal

Waste attracts pests and can cause food contamination. It can also cost you points on your health inspection. Find out the top 10 rules for waste disposal in a food business. aste attracts pests and can cause cross-contamination of food that is being served to customers.

Food businesses must have the proper equipment in place to manage both liquid and solid waste, and have strict procedures for waste management, including regular garbage collection.

1. Remove food scraps from the kitchen daily – or more frequently if required.
2. Arrange regular garbage collection. Most food businesses require garbage collection at least twice a week.
3. Do not allow garbage containers to overflow. Move overflowing waste to other containers.
4. Regularly hose down and clean garbage containers.
5. Always use a garbage liner for garbage containers. This is a good way to ensure that the garbage container is kept as clean as possible and that harmful bacteria do not have time to grow on the inside of the unit itself.

5. Waste disposal and your Food Safety Plan

Rules for proper waste disposal are only one part of a robust Food Safety Plan. Food safety best practices and monitoring techniques are critical at every stage of the food production process, from delivery to service.

Your Food Safety Plan should document the specific rules for disposal of food waste and the safe handling of food, as well as the details of your employee training programs. Everyone who handles food — including food waste — in your business must be properly trained to do so safely.

6. Food Wastes Disposal Methods

Food waste is one of the most prominent waste streams across Middle East, especially in GCC region. The mushrooming of hotels, restaurants, fast-food joints and cafeterias in the Middle East region has resulted in the generation of huge quantities of food wastes. The proportion of food waste in municipal waste stream is gradually increasing and hence a proper food waste management strategy needs to be devised to ensure its eco-friendly and sustainable disposal in the Middle East.

Food waste is an untapped energy source that mostly ends up rotting in landfills, thereby releasing greenhouse gases into the atmosphere. Food waste includes organic wastes generated in hotels, restaurants, canteens, cafeterias, shopping malls and industrial parks in the form of leftover food, vegetable refuse, stale cooked and uncooked food, meat, teabags, napkins, extracted tea powder, milk products etc. It is difficult to

treat or recycle food waste since it contains high levels of sodium salt and moisture, and is mixed with other waste during collectio.

7. Food waste can be recycled by two main pathways:

Composting: A treatment that breaks down biodegradable waste by naturally occurring micro-organisms with oxygen, in an enclosed vessel or tunnel or pit

Anaerobic digestion or biogas technology: A treatment that breaks down biodegradable waste in the absence of oxygen, producing a renewable energy (biogas) that can be used to generate electricity and heat.

Composting

Composting provides an alternative to landfill disposal of food waste, however it requires large areas of land, produces volatile organic compounds and consumes energy. Compost is organic material that can be used as a soil amendment or as a medium to grow plants. Mature compost is a stable material with a content called humus that is dark brown or black and has a soil-like, earthy smell. It is created by: combining organic wastes (e.g., yard trimmings, food wastes, manures) in proper ratios into piles, rows, or vessels; adding bulking agents (e.g., wood chips) as necessary to accelerate the breakdown of organic materials; and allowing the finished material to fully stabilize and mature through a curing process.

Anaerobic Digestion

Anaerobic digestion has been successfully used in several European and Asian countries to stabilize food wastes, and to provide beneficial end-products. Sweden, Austria, Denmark, Germany and England have led the way in developing new advanced biogas technologies and setting up new projects for conversion of food waste into energy. The relevance of biogas technology lies in the fact that it makes the best possible utilization of various organic wastes as a renewable source of clean energy. A biogas plant is a decentralized energy system, which can lead to self-sufficiency in heat and power needs, and at the same time reduces environmental pollution.

Of the different types of organic wastes available, food waste holds the highest potential in terms of economic exploitation as it contains high amount of carbon and can be efficiently converted into biogas and organic fertilizer. Food waste can either be utilized as a single substrate in a biogas plant, or can be co-digested with organic wastes like cow manure, poultry litter, sewage, crop residues, abattoir wastes etc.

Check your progress - 3
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.
5. What is sanitation?

6. What are the different types of sanitation?

5. What is sanitation?

The word sanitation is derived from the Latin word sanitas, meaning "health." Applied to the food industry, sanitation is "the creation and maintenance of hygienic and healthful conditions." It is the application of a science to provide wholesome food processed, prepared, merchandised, and sold in a clean environment by healthy workers; to prevent contamination with microorganisms that cause foodborne illness; and to minimize the proliferation of food spoilage microorganisms. Effective sanitation refers to all the procedures that help accomplish these goals

6. What are the different types of sanitation?

- **Basic sanitation**:
  Refers to the management of human faeces at the household level. It means access to a toilet or latrine.
- **Onsite sanitation**:
  The collection and treatment of waste at the place where it is deposited.
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  Refers to the hygienic measures for ensuring food safety. Food hygiene is similar to food sanitation.
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  Refers to safeguarding the home environment (the dwelling and its immediate environment).
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  The control of environmental factors that form links in disease transmission. This category includes solid waste management, water and wastewater treatment, industrial waste treatment and noise and pollution control.
- **Ecological sanitation:**
  The concept of recycling the nutrients from human and animal wastes to the environment.

12.6. LET US SUM UP

In this unit looks about the Sanitation is the creation and maintenance of hygienic and healthful conditions. It is an applied science that incorporates principles regarding the design, development, implementation, and maintenance of hygienic practices and conditions. Sanitation is also considered to be a foundation for food safety assurance systems.

Then we studied about some of the important type's personal hygiene.

We also discussed about care of hands and Choosing equipment with sanitary features has been simplified by a number of equipment standards provided by organizations and manufacturers.

The last part of the unit focused on the improve sanitation in foodservice establishments, the facility and equipment should be designed for clean ability.

12.7. UNIT- END- EXERCISES

1. What is the Importance of Personal Hygiene
2. What are the steps for proper handwashing?
3. When to wash hands?
4. Explain Critical aspects and rationale of cleaning and disinfection programmers.
5. What is personal hygiene?
6. Explain the public health importance of personal hygiene.
7. Why is it inadvisable to share nail cutters?

12.8. ANSWER TO CHECK YOUR PROGRESS

1. What are the Importance of Personal Hygiene

   Proper personal hygiene is critical in any food service premise.

   Personal hygiene includes:

   - ❖ Showering and bathing regularly
   - ❖ Keeping hair clean hair and covered or tied back
   - ❖ Keeping clean clothing and footwear that is used only at work
   - ❖ Handwashing regularly
   - ❖ Using clean utensils for tasting food
   - ❖ Using separate cloths for cleaning and wiping plates
2. What are The steps for proper handwashing ?
   - ❖ Wet hands with warm water.
   - ❖ Apply liquid soap and lather for at least 20 to 30 seconds.
   - ❖ Scrub backs of hands, wrists, all fingers, and under nails.
   - ❖ Rinse under running water, pointing down toward the drain.
   - ❖ Dry with a paper towel.
   - ❖ Turn off taps and open bathroom door using the paper towel.

8.9 SUGGESTED READINGS

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UNIT XIII – FOOD PACKAGING – BAR CODING – PACKAGING LAWS AND REGULATIONS

13.1. Introduction
13.2. Objectives
13.3. Food Packaging
13.4. Bar coding
13.5. Packaging laws and regulations
13.6. Let Us Sum Up
13.7. Unit- End- Exercises
13.8. Answer to check your Progress
13.9. Suggested Readings

13.1 INTRODUCTION

All processed foods require packaging so as to make the products available to the end user, the consumer, in desired quality and form. It is necessary for the packaging material to protect the products in all aspects, from the point of origin until their consumption. Packaging, therefore, must withstand the local climatic, storage, transport and handling conditions.

13.2 OBJECTIVES

After going through the unit you will be able to;

- Understand the preserve, protect, and maintain the contents in a fit and palatable condition.
- To withstand the chosen selling and distribution method
- To furnish a design and appearance which should be attractive to the customer, easy to open, dispense, store and finally dispose of.
- To provide an economical container.
- To make it easier and safer to transport.
- To prevent or minimize losses of the product.
- To provide a convenient means for dispensing the product

13.3 Food Packaging

Food packaging is defined as a co-ordinated system of preparing food for transport, distribution, storage, retailing, and end-use to satisfy the ultimate consumer with optimal cost (Coles et al., 2003). Food packaging is an essential part of modern society; commercially processed food could not be handled and distributed safely and efficiently without packaging. The World Packaging Organization (WPO) estimates that more than 25% of food is wasted because of poor packaging (WPO, 2009). Thus, it is clear that optimal packaging can reduce the large amount of food waste. Moreover, the current consumer demand for convenient and high-quality food products has increased the impact of food packaging.

In India, the conditions through which packaged foods must travel are indeed difficult, and the distribution chain is often very long. Some of the environmental factors are controllable by packaging.

Table 13.3.1 The pertinent properties of a package and the environmental factors to be gaurded against are briefly summarised as follows:

Package Properties	*Environmental Factors*
Strength Permeability Light transmission Thermal conductivity, Reflectivity, Porosity Penetrability	Mechanical Shocks Pressure of O_2 watervapour, etc. Light intensity Temperature Biological Agents

The protection offered by a package is determined by the nature of packaging materials and by the type of package construction.

13.3.1 Basic Packaging Materials for Flexible Packaging

The basic flexible packaging materials that come into question, either in individual or in laminated form, are paper, polyethylene, (coated) cellophene, polypropylene and aluminium foil.

1) **Paper**

Basically paper is opaque but it has a high water vapour transmission rate as well as permeability to gases and odours, and it is not heat- sealable. A very considerable proportion of packaged foods is stored and distributed in packages made of paper or paper-based materials. It seems probable that because of its low cost, ready availability and great versatility, paper will retain its predominant packaging position for some time to come. Paper consists primarily of cellulose fibres which are obtained from wood or other cellulose containing materials by one of several pulping processes.

The packaging properties of paper vary considerably, depending on the manufacturing processes and on additional tieatmenls to which the finished paper sheet may be subjected. Its strength and mechanical properties depend on mechanical treatment of the fibres and on the inclusion of fillers and binding materials. The physico-chemical properties, such as permeability to liquids, vapours and gases can be altered profitably by impregnating, coating and laminating using waxes, plastics, resins, gums, adhesives, asphalt and other substances. Laminated waxes and coated papers serve as protective materials. The flexible packaging applications include the use of papers for wrapping materials, as well as the manufacture of bags, envelopes, liners, and overwraps where kraft paper, greaseproof papers, glassines and waxed papers are used. Rigid paper containers include a variety of types, varying in materials, e.g., cartons, boxes, fibre cans, drums, liquid-tight cups, tetrahedral packs and many others, and methods of construction that employ paper board, laminated papers, corrugated board, and the specially treated boards and papers. Frequently, the paper containers have liners or overwraps, made usually of protective grades of papei, plastics or metal foil.

For snack foods, only such papers as glossive wax-coated and hot melt coated papers would be considered for making bags. In the United States glassine has been used by snack food producers in laminated form for many years. In lamination with other materials such as cellophane and oriented polypropylene, glassine's strongest characteristic is its stiffness. Glassine in itself is a good barrier to the oils that cover all fried snack products. It is also a better gas barrier than other papers if it carries a PVDC coating. There are many coatings for glassine paper that are used to provide good moisture and aroma barriers and good seals on form-fill equipment. Ethyl vinyl acetate wax blends are one type, PVDC emulsion or solvent coatings are the other types. Glassine can also be laminated with polyethylene.

2) Plastics

Plastics are organic polymers of varying structure, chemical composition and physical properties. The types of plastics used in food packaging are cellophanes, celluloses, polyolefins, vinyl derivatives, polyesters, pliofilm, polyfluorocarbons and polymer alloys.

3) **Cellophanes:** Cellophanes are natural rather than synthetic polymers. The major constituent of cellophanes is cellulose; it contains, in addition, a plasticizer such as glycerol or ethylene glycol, which is materials of low volatility, and if added to plastics, reduces the attractive forces between the polymer chains, resulting in better flexibility. But it offers no protection to the diffusion of water-vapour. The packaging properties of cellophanes depend upon the types of protective agents used for coatings, such agents being nitrocellulose, waxes, resins and synthetic polymers. Coated cellophane is more transparent, has a limited water-vapour transmission rate, and is highly impermeable to gases and odours; grease cellulosics are cellulose acetate ethyl-cellulose, and cellulose nitrate produced from cellophane that have properties similar to cellophane. But these do not find wide applications in food packaging. However, the cellulose films are often used as external plies in laminate structures, such as cello/poly, cello/foil/poly, etc. When polymercoated cellophane is used as the inner ply closest to the product, it acts as an excellent grease barrier.

4) **Polyethylene:** Basically, polyethylene is heal sealable and transparent and has a low moisture vapour transmission rate (MVTR), but is highly permeable to gases and odours. Increasing density results in lower MVTR and 02 permeability, higher tensile strength and reduced clarity, but improves both resistance to fats and oils and rigidity. Additionally, for the higher density materials, their higher softening temperature necessitates higher sealing temperatures. High density polyethylene (HDPE) is used in film form as well as in producing rigid plastic containers including milk bottles. The low density polyethylene (LDPE) is widely used for packaging foods in bags or as an over-wrap due to its high flexibility and low cost.

5) **Polypropylene (PP):** is used in competition with regenerated cellulose films as an external ply of laminates. The most interesting properties of polypropylene films in relation to packaging are floss and transparently easy printability, good weldability, puncture resistance,

impermeability to water and water-vapour, high yield, uncreasability and excellent behaviour over a wide temperature range. PVDC-coated grades are used for achieving low permeability of Oz and to a lesser extent to moisture vapour.

Polypropylene film gives outstanding performance in the following double or triple laminates; aluminium/PP, PP/Polyamide, PP/Cellulose, PP/Paper. In the packaging of food products, particularly perishables, aluminium/PP laminates may be used with advantage. I'P makes the laminate heat-sealable and sterilizables polyester is polyethylene tereph-thalate, a condensation product of ethylene glycol and terephthalic acid. It is known as Mylar in the US, has excellent strength and inertness and is widely used in food pouches as the outer, abrasion-resistant layer of laminations.

6) **Pliofilm:** is rubber hydrochloride and its properties depend upon the type and amount of plasticizer added.

7) **Polyfluorocarbons:** Teflon and FEP, which are equivalents of polyeth- ylenes with hydrogen replaced by fluorine, have remarkable inertness and high permeability to 02. On the contrary, fluorochloroethylene has an extremely low permeability to all gases and is, in particular, very effective as a water-vapour barrier. Polyvinyl fluoride is intermediate in permeability, but has an excellent resistance to sunlight.

8) **Polyamides:** are condensation polymers of diamines with diacids, and are called nylons. They are inert, heat-resistant and have excellent mechanical properties. They are usually coated, or used in combination with other materials to produce low permeable inert packaging materials.

Table 13.3.1 Comparative properties of some films for packaging

1) **Water-Soluble and Edible Films:** aim at minimizing solid wastes and stem from ecological considerations. They include polyvinyl

	PP Oriented	PP Unoriented	LDPE	HDPE	PVC	PVDC
Elongation at break%						
Machine Direction	100-170	300-500	200-800	300	40-260	22-38
Cross Direction	20-30	300-600	300-700	—	5-250	15-38
Water absorption	0.01	0.01	0.01	—	0.05-5	0.01
Melting Point°C	168-170	168-170	107-112	122-136	—	155
Water Vapour permea-bility at 25°C gm.25 micron m^2 24 hr	2-5	7.5-8	12	5-10	40.100	1-2
Permea-bility to 02 at 25°C cm^3. 25 micron m^2 24 hr at m	500-800	700-5,300	10,000	520-3,900	2,000-1,000	60
Permea-bility to CO_2 at 25°C cm^3. 25 micron m^2 24 hr. at m	1,300-2,000	9,500-15,000	40,000	39,000-10,000	1,500-15,000	180

alcohol, some cellulose derivatives, as well -is other polysaccharides, including those derived from the linear starch component-amylose. Some proteins, especially collagen, are also used.

2) **Other Films:** Ionomers are polymeric films containing ionized groups. They are particularly resistant to effects of low temperatures and have better film strength due to ionic cross-links. Heat-resistant materials suitable for production of sterilizable package are yet to be developed.

13.3.2 Retort Pouch Materials

Retort pouch is a two-in-one flexible laminated food package that has the advantages of a metal can and 'boil-in-bag' used for thermally processed foods. As early as 1974, the first commercial retorts pouches were introduced in the USA and Canada, and now more than six companies have developed fully integrated systems. Fifteen years ago, retortable food was introduced in the Japanese market and the total production shipment of retortable food is estimated to have amounted to 6.2 billion yens in 1982 as compared to 48.7 billion yens in 1979. In the UK, a 'Meta packs' line, said to be the first commercial unit, has been introduced. 'Meta pack' itself is a laminate of C37 copolymer and foil. In India, non-availability of the right-type of packaging material has hindered the adoption of retort- able pouches although progress has been made using available polypropylene as basic film without lamination. In future years it is expected to make significant in-roads in packaging.

13.3.3 The requirements for a pouch film are:

a) Gas permeability less than 15 ml/m2/24/atm
b) Water-vapour transmission rate (WVTR) less than 0.8 g/m2/24hr
c) Resistance to temperatures from below 32°F to at least 25CTF
d) High hydrophobic properties
e) Low cost of material and package fabrication
f) Suitability for food use
g) Resistance to fats and oils
h) Heat scalability over-wide range of temperatures
i) Chemical inertness and dimensional stability
j) (Good heat penetrability and capacity to being handled on automaticfabricating and filling equipment
k) Physical strength to resist handling abuse.
l) Good durability, printability and consumer appeal:

13.3.4 The performance requirements for sterilizable materials are as under:

1. Sterilization temperature 116-145°C
2. Oxygen permeability OCC/M:/24 hours
3. WVTR og/M2/24 hours
4. Seal strength: 2-3.5 kg/10 minutes
5. Bond Strength: 150-500g/10 minutes
6. Heat Seal range: 160-260'C
7. Thickness tolerance ± 2 microns or ±7.0 g/rrr

8. Burst Strength 7.5 kg/15 mm Seal
   17-2 x 10 Pa for 30 seconds
9. Residual Solvent (taint) ?0 mg/m"
   0.5 ppm as toluol

The normal dimensions of pouches range from 108 x 152 mm to 203 x 279 mm for 100-900 g product. Norma! thickness of pouches range from 16-33 mm. Design feature and variations of four side pouch include (a) Tear notches for easy opening; (b) unfilled void to minimise product contamination at seal area; (c) secondary closure seals or band sealing with or without trimming to eliminate an unsealed flap or lip, and (d) rounded internal or external pouch corners to improve appearance, performance and to lower the incidence of punctures.

1. **Glass:** has an excellent inertness, and when inert liners are used for closures, there is no interaction between food and package.
2. **Tin Foil:** which was much used at the beginning of the century, has disappeared because of its high price and the progress in aluminium manufacture.
3. **Aluminium Foil:** It has the best barrier performance of any substrates used in flexible laminate manufacture. Since aluminium foil, on its own, is not particularly strong, it has to be laminated to some stronger material to reinforce it and make it efficient as a barrier to water-vapour and oxygen. The cheapest reinforcement is paper. Whereas the strength of laminates is almost entirely due to the film or paper used, the barrier properties of this laminate will depend on the foil. The foil can also be reinforced by regenerated cellulose, polyester, polyethylene and polypropylene. These films strengthen the foil and protect it against mechanical damage and also help to block any leakage due to inadvertent pinholes and perforations in the foil. It is, however, very important that the package made out of such foil laminate is sealed properly.
4. **Metal Cans:** might appear to be the best from the point of view of shelf- life and preservation and the physical characteristics of the product. However, the very high cost of the tin can would be out of proportion to the relatively low cost products per unit weight or volume. Even the composite can with multiply paper/laminate body with metal ends which is less expensive than metal cans are widely used for snack foods only in more advanced countries. These cans are often provided with convenient pull-tab-opening tops and, thus, can openers are not needed.

In order to obtain satisfactory packaging properties, it is necessary to combine two or more different materials as mentioned below:

1. Plastic combinations containing two or more plastic films laminated with various types of synthetic and natural adhesives.
2. Plastic, silicone, and wax coatings on package made of metals, paper, wood, and other materials.
3. Rigid cans made of paper with metal bottoms and tops.
4. Plastic films with thin metallic coating.
5. Barrier materials constructed of as many as 6-7 materials including paper, textiles, metals, plastics, waxes and resins.

13.3.5 The printing or labeling on the package should serve

a) to identify the contents as to the type and quantity

b) to identify the manufacturer's brand and quality grade
c) to induce impulse buying by attracting the buyer's attention
d) to instruct the user on how to use the product
e) to carry other information as is required by food laws and other acts
f) to inform the consumer the nutrient composition and the special therapeutic use, if any, and
g) to protect the consumer against exploitation.

1. **Lids:** All containers, whether prefabricated or thermoformed on the production line, must be closed after filling. The two categories of closures are (a) Snap on-lids, and (b) heat sealable lids.

Caps require fairly flexible edges, combined with a resistance to tearing sufficient to allow opening and closing several times. They are produced either by thermoforming or by injection molding. Most snap-on-lids are made of PVC film, either transparent (if the container is sealed by a printed aluminium lid), or pigmented.Specially designed projections grip the edges of the container. In certain cases, e.g., for closing glass or stoneware jars, snap-on-lids of injection moulded polyethylene are used.

13.3.6 Package design requirements: The selection of a package should be based on the following market criteria:

1. Package size
2. Nature of the product and its sensitivity to varying environmental conditions.
3. Barrier requirements of the packaging materials
4. Convenience factors to be built into the package
5. Shelf-life -
6. Need for reusability
7. Dealer/retailer requirements
8. Shipping requirements
9. Mode of storage
10. Distribution pattern
11. Disposal of used package
12. Package cost
13. Process of packaging (manual, semi-automatic or fully automatic)
14. Product shape and volume (ratio of surface area to volume), and
15. Product characteristics that include
    a) initial moisture content
    b) relative humidity
    c) fat content
    d) presence of vitamins
    e) presence of other additives

The properties required for a packing material would obviously depend upon the product that is to be contained in it. In other words, a package must ensure that the product is adequately protected, and is:

(a) Moisture proof: All products have a certain amount of moisture present in them at the time to manufacture. Depending upon this initial moisture level, the products tend to absorb or lose moisture when exposed to varying humidity and temperature levels. A product becomes unpalatable beyond a certain level of moisture in it due to changes either in characteristic or in physical state. This level of moisture is called the

critical moisture content. Protection against moisture penetration is required to prevent the crispy product from becoming soggy and tough.

(b) Air, Light, and Heatproof: The hazard from air, light and heat is greater with products of high fat content. Oxygen and light produce oxidative rancidity of oils in these products. This is further accelerated by heat, free circulation of air passage of atomic rays by light transmission, presence of trace elements like copper, and so on. It, therefore, calls for the use of oxygen and light barrier materials, particularly for products susceptible to rancidification.

(c) **Oil and Grease Proof:** As the oil and grease in the product tend to stain the packaging material, leading to delamination and/or ink deterioration and resulting in an unattractive appearance, the packaging material should be adequately grease proof. Besides the above, a good package should cover the following important aspects of product packaging. Odour permeation barrier: A food product loses its flavour, and aroma, and picks up external odour and changes its characteristics during storage. It is, therefore, imperative that the packaging material is a good barrier to odour permeation.

(d) Breakage and fragility: For fragile products, rigid or stiff packaging material plays an important role in successful merchandising. The use of vertical racks and display cabinets again requires adequate stiffness of the material to be used for fabricating the package.

(e) Machinability: Products are often packed on fast automatic machine and, therefore, the materials should be_amenable to such conditions. This is true with regard to, both, pre made and filled bags, boxes, and to form-fill-seal simultaneous operations.

In order to evaluate the suitability of a package for a specific product, the following information is needed by the packaging manufacturer.

a) Detailed information on product, including ingredients used and the method of preparation
b) Shelf-life of the product
c) Initial moisture content and deterioration moisture content of the product if it is hygroscopic
d) Sensitivity of the product to light
e) Acidity or alkalinity (PH) of the product
f) Weight of the unit pack and the bag or pouch size
g) The speed, temperature, well time, pressure, etc, of the machine employed in packaging
h) The testing procedure that will be used by the packer
i) The storage conditions of the filled packs, both, at the manufacturing site and at the retail shops
j) The required mechanical properties of the films or laminates like tensile strength tear strength, burst strength and heat seal strength.

13.3.7 Types of Packaging: There are two main categories of packaging foods:

(1) "Hie retail outlet, either a single-serve or multi-serve, and

(2) that comprising either institutional packaging for mass feeding centres, or marketing through ration shops or selling through a middle man who will later repack the food in smaller pouches or bags for retail sale- 1 he

retail outlets for a snack food can be predicted to be cinema halls, railvvay stations, picnic spots, grocery stores, and roadside vendors.

For single serve retail outlets, flexible pouch, either preformed oi produced through a form-fill seal operation, would be the best. As for the packing material, starting with a simple glassine or butter-paper preformed bag, one of the laminates could be chosen, with shelf-life \is- a-vis cost as the ultimate governing factors. In case of perishable snack foods, regular replenishment of the stocks is important because stocking
more than a few days supply is uneconomical.

For wholesale marketing, bulk packaging would be opted due to stringent budget limitations, as, even with a cheap packing material, the small packs would make the product price exhorbitant. In many of the food products marketed through traditional commercial channels, such as weaning foods, the packaging often constitutes 33 percent of the price paid by the consumer for commercially marketed products compared to 4 percent of the total product cost by bulk packing.

The concept of share-a-pack is a practical proposition where a number of consumers or end-users share-a-pack at a reasonable low cost.

A further step in the concept of 'share-a-pack' is the returnable container where a pack is not only shared by a number of consumers, but is shared again and again a number of times, offering further scope of economizing on packaging expenses.

13.3.8 Effect of Packaging on the Nutritive Value of Foods

Some of the light catalyzed reactions in foods are oxidation of fats ana oils destruction of riboflavin and other water soluble vitamins, changes in proteins and aminoacids. The protection offered by the package falls into two categories; viz.

(a) Direct protection by absorption or reflection of all or a part of the incident light.

(b) Indirect protection by preventing access of a component (e.g., atmospheric 02) necessary for the light catalyzed reaction.

The protective characteristics of a packaging material can be improved by special treatments. Glasses are frequently modified by inclusion of colour producing agents or by application of coatings. Modification of plastic materials may be achieved by incorporation of dyes or by applica¬tion of coatings. Losses of ascorbic acid and riboflavin have been found to be retarded by these methods.

Packaging materials, by affecting the rate of heat transfer to and from the food products, help in retention of nutrients that are sensitive to heat. For control of temperature, packaging material has to be good insulator. Synthetic foams of polystyrene and of polystruethene have excellent insulation properties. Freezing and thawing rates of frozen foods depend upon the type of containers. The quality of foods and their nutritive value, in turn, depend upon the rate of freezing.

Oxidation of fats and oils, deterioration of the biological value of proteins and the destruction of some vitamins may be the result of atmospheric oxygen. A number of amino acids and amino acid residues of proteins are highly susceptible to oxidation; and ascorbic acid, vitamin A and E are particularly susceptible to oxygen. The availability of oxygen to

packed foods depends upon the nature of the container. Adequately sealed cans and glass containers effectively prevent the interchange of gases between the food product and atmosphere. In flexible packaging, however, the diffusion of gases depends only on the effectiveness of closure, but also on the permeability of the packaging material (See Tables), which in turn depends upon the physico-chemical structure of the barrier.

Table 13.3.2 Packaging Materials and Their Permeability to O_2

Material	Permeability Range (C.C) (Mil). (Day.1) (M-2) (ATM-1)	
Conventional polyethylene	6,000 - 15,000	
HDPE	1,500 - 3,000	
Pilofilm	200 - 5,000	(depending on type and amount of plasticizer)
Plain Cellophane	20 - 5,000	(depending on humidity)
Polyvinyl fluoride	25 - 100	
Mylar	50 - 100	
Cellulose Acetate	1,000 - 3,000	
Coated and waxed paper	100 -15,000	
Foil lamination	0	
Plastic Laminations	10 - 400	
Poly-trifluorochlorocthylene	50 - 1,000	(depending on plasticizer)
Silicon rubber	Over 250,000	

Packages as mentioned elsewhere, are made from many components, having varying chemical and physical characteristics. Some of these components may react with the contents of the package. In the field of toxico- logical implications of food packaging, new techniques have been developed for the determination of trace quantities of specific components of packaging materials and enamels, and specific substanccs of especially high potential linger have been tested utilising extremely sensitive methods. Recent concern about potential toxibility of variousheavy metals has resulted in on-going research on transfer of contaminants from various metallic containers.

In metal containers, application of inert coatings, enamels and lacquers guards against reaction between food and package. Metal contamination is an important factor in oxidative deterioration of fat in biscuits.

Table 13.3.3 Table water Vapour Permeability of Packaging Materials

Material	Permeability Range (GM). (MIL). (24 hrs)-1 (100 Sq.in)-1
Plain Cellophane	20 - 1000
Nitrocellulose coated cellophane	0.2 - 2.0
Polyethylene, conventional	0.8 - 1.5
Polyethylene, low pressure	0.3 - 0.5
Vinylchloride based films	0.5 - 8.0
Aluminium foil 0.00035" thick "0.0014 in"	0.1 - 1.0
Plastic paper foil laminations	less than 0.1.
Waxed paper	0.2 - 15.0
Coated papers	0.2 - 5.0
Mylar	0.8 - 1.5
Polypropylene	0.2 - 0.4
Silicon Rubber	0.2 - 0.4 7,000
Poly-trifluorochloroethylane	0.01 - 0.10

Penetration of packaging material by free oil from food results in development of rancidity and, thus, the nutritive value of the packaged food. Grease-proof packaging materials help in controlling the penetration of fat and oil from the food.
The developments in packaging of some of the food products are discussed in the following pages.

13.3.9 Packaging of Bakery Products

Prior to 1910, most bread was sold unwrapped in United States. Between 1910 and 1920, wax paper was in use followed by cellophane in 1920 and coated cellophanes by 1930. Later, a rapid succession of varieties of polyethylene and polypropylene films were utilised; today 80 per cent of all bread in the US is packed in low density polyethylene bags.

The caloric value of bread and the biological value of bread protein are not affected by the package, while there is a controversy about the retention of riboflavin in bread. Thiamin and niacin has good stability under normal distribution conditions. The optical properties of packaging material are of minor importance in preservation of riboflavin content of bakery products with a well-developed crust. In partially baked rolls and similar bakery products, however, the retention of riboflavin appears to be determined in part by light-transmission characteristics of the package.

13.3.10 Dairy Products

Glass bottles were used for virtually all fresh milk sold in the United States in 1950. Today 90 percent of the milk is sold in plastic-coated paperboard. Production of oxidized off-flavours and the degradation of ascorbic acid, riboflavin, and methionine are the undesirable effects in fluid milk due to exposure to light. Thus, milk stored in containers that exclude air retains its palatability, appearance and amino-acid content.

Paperboard carton and returnable plastic jug are both inadequate for protection of milk from loss of flavour and nutritional value under the high intensity lighting in super markets. Black pigmented opaque polyethylene has been found to give better protection from losses of riboflavin and ascorbic acid in milk. Clear glass bottles result in nutrient losses. Prevention of exposure to light is the most important factor in prevention of surface oxidation of packed butter. Prevention of moisture loss, off-flavour development, and appearance defects necessitate the use of protective packages, such as laminated foils and low-permeability plastics for packaging of cheese.

Although polypropylene has long been known as a laminating material, i's use for thermoforming is recent. It possesses excellent characteristics for packaging of unripened cheese, being resistant to fats and to temperatures upto 130°C for 30 minutes.

Coming Into contact with the metal causes the formation of aluminium lactate, which attack the wall of the pack or lid, sometimes perforating it. So aluminium containers made of 15 to 20 mm thickness, rectangular with straight walls or cylindrical with corrugated sides, with aluminium lid is only applicable to unripened cheese with high solid contents. The sides of the container and the lid are folder over and heat-sealed together.

Because of the high permeability to water-vapour and the risk of micro-biological maceration of paper, the surface in contact with the soft cheese is sometimes coated. The coating materials are most often based on a mixture of paraffin and microcrystalline waxes.

Check your progress - 1
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.

1. What is Packaging of Foods?
2. What are the Types of Food Packaging?

1. What is Packaging of Foods?

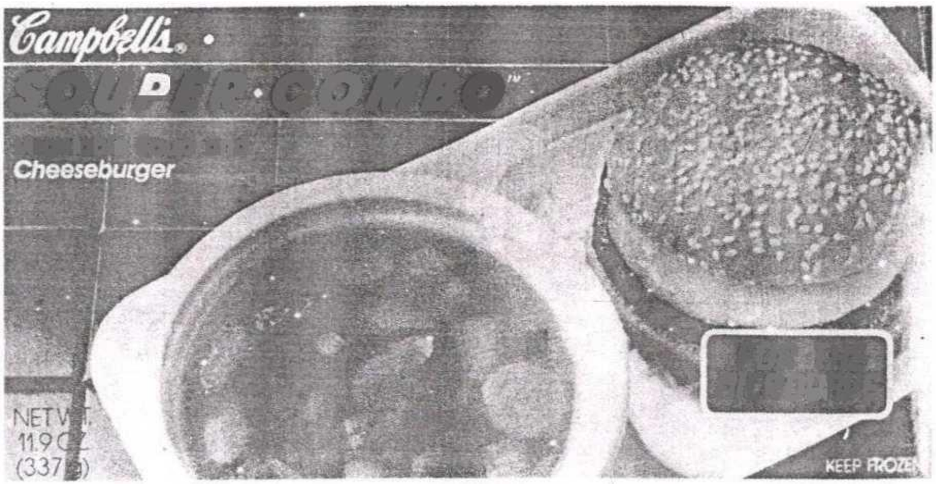
Food packaging is defined as a co-ordinated system of preparing food for transport, distribution, storage, retailing, and end-use to satisfy the ultimate consumer with optimal cost (Coles et al., 2003). Food packaging is an essential part of modern society; commercially processed food could not be handled and distributed safely and efficiently without packaging. The World Packaging Organization (WPO) estimates that more than 25% of food is wasted because of poor packaging (WPO, 2009). Thus, it is clear that optimal packaging can reduce the large amount of food waste. Moreover, the current consumer demand for convenient and high-quality food products has increased the impact of food packaging.

13.4 Foods and selection of packing materials

13.4.1 Functions of Food Packaging

Packaging is an essential part of processing and distributing foods. Whereas preservation is the major role of packaging, there are several other functions for packaging, each of which must be understood by the

food manufacturer. Indeed, faulty packaging will undo all that a food processor has attempted to accomplish by the most meticulous



manufacturing practices. Packaging must protect against a variety of assaults including physical damage, chemical attack, and contamination from biological vectors including microorganisms, insects, and rodents. Environmental factors such as oxygen and water vapor will spoil foods if they are allowed to enter packages freely. Contamination of foods by microorganisms can spoil foods or cause life-threatening diseases. Many foods would not survive distribution without physical damage were it not for the protection afforded by packaging.

In order to be successful, packaging must also aid consumers in using products. Food packaging should have features which make the product easier to utilize and add convenience. This may be as simple as reclosure after partial use or as complicated as aiding in the microwave cooking of a product (Fig. 8.4.1). Many new food products are in reality standard foods packaged in a new way that aids in preparation or storage. Aseptically packaged milk is an example.

Food packaging must also be able to communicate and educate. It is the package which identifies the product for the consumer. In addition to convincing consumers to buy a product, the package must also inform consumers about how to prepare or use the product, contents or amount of product contained, ingredients, nutritional content, and other pertinent information. Much of this information is required by specific laws in many

Figure13.4.1 Microwavable soup and sandwich combination in which the package and product are specifically designed for thawing and heating in a home microwave oven.

The package is also an important part of the manufacturing process and must be efficiently filled, closed, and processed at high speeds in order to reduce costs (Fig.13.4.1). It must be made of materials which are rugged enough to provide protection during distribution but be of low enough cost for use with foods. Packaging costs,

which include the materials as well as the packaging machinery, are a significant part of the cost of manufacturing foods, and in many cases,

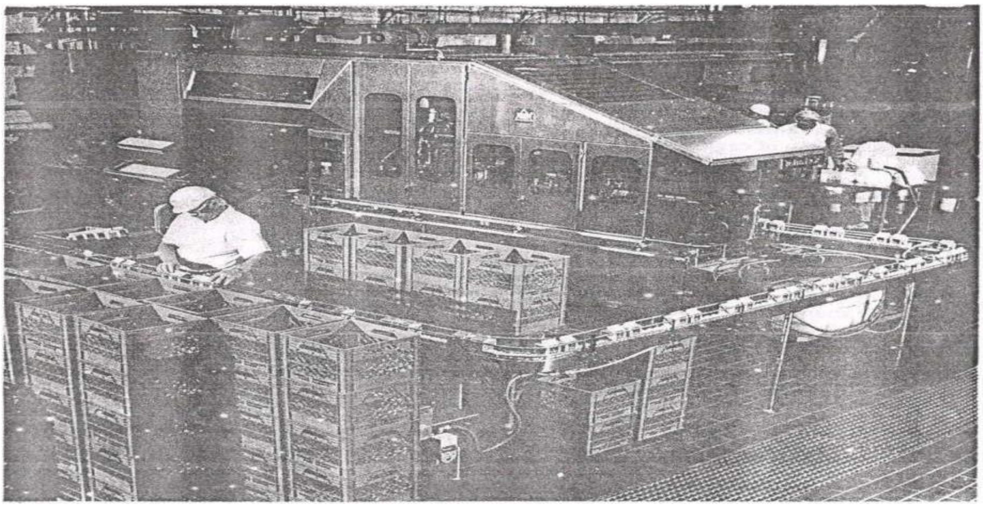
these costs can be greater than the cost of the raw ingredients used to make the food. Therefore, packaging materials must be economical, given the value of the food product.

13.4.2 Requirements for Effective Food Packaging

Some of the more important general requirements of food packages are that they (1) be nontoxic, (2) protect against contamination from microorganisms, (3) act as a barrier to moisture loss or gain and oxygen ingress, (4) protect against ingress of odors or environmental toxicants, (5) filter out harmful UV light, (6) provide resistance to physical damage, (7) be transparent, (8) be tamper-resistant or tamper-evident, (9) be easy to open, (10) have dispensing and resealing features, (11) be disposed of easily, (12) meet size, shape, and weight requirements, (13) have appearance, printability

Figure 13.4.2 A Modern high- speed packaging line for filling paperboard based cartons with liquid foods and beverages such as milk or soups. *Courtesy of Cornell University Photo Services.*

All common polymers used in food packaging allow the transfer of



moisture and gases such as 02 or water vapor directly through them by a process known as permeation. However, polymers can inhibit permeation to different degrees depending on their chemical makeup and physical structure. Some polymers are high barriers, whereas others offer little resistance. The same holds true for moisture and oxygen transfer through films. Moisture protection is a two-way affair. Dry foods should not absorb moisture from the atmosphere, and moist foods should not lose moisture and dry out. There are exceptions such as permeable films that allow the escape of moisture from respiring vegetables. Barrier against fat migration is needed to keep oils and fats from passing through wrappings. A material that is a high moisture barrier is not necessarily impervious to fat. Similarly, a greaseproof material is not necessarily impervious to moisture.

13.4.3 TYPES OF CONTAINERS

i) Primary, Secondary, and Tertiary

Food packaging can be divided into primary, secondary, and tertiary types. A primary container is one that comes in direct contact with the food, for example, a can or ajar. Obviously, primary containers must be nontoxic and compatible with the food and cause no color, flavor, or other foreign chemical reactions. A secondary container is an outer box, case, or

wrapper that holds or unitizes several cans, jars, or pouches together but does not contact the food directly. Secondary containers are a necessary part of food packaging. It would not be possible to distribute products in glass jars, forexample, without the corrugated secondary carton to protect against breakage. As pointed out above, primary containers (i.e., those contacting foods) have several important functions. Secondary containers have fewer but no less important functions. Secondary containers must protect the primary containers from damage during shipment and storage. They must also prevent dirt and contaminants from soiling the primary containers and must unitize groups of primary containers. Corrugated fiberboard is most commonly used to make secondary shipping cartons. There are strict standards on the construction and use of secondary containers to ship products. The size and strength of carton used must be selected for each type of product to be shipped. Cartons come in several different designs, each of which is intended for different types or forms of products (Fig. 13.4.3). Damage during shipment which can be shown to result from inadequate secondary containers is the responsibility of the food manufacturer, not the shipping agent. Except in special instances, secondary containers are not designed to be highly imperious to water vapor and other gases. Dependence for this is placed on the primary container.

Tertiary containers group several secondary cartons together into pallet loads or shipping units. The objective is to aid in the automated handling of larger amounts of products. Typically, a fork lift truck or similar equipment is used to move and transport these tertiary loads (Fig. 13.4.4).

13.4.4 Form-Fill-Seal Packaging

Containers may be performed, that is, fabricated by the packaging manufacturer; or they may be formed in-line by assembly from roll stock or flat blanks just ahead of

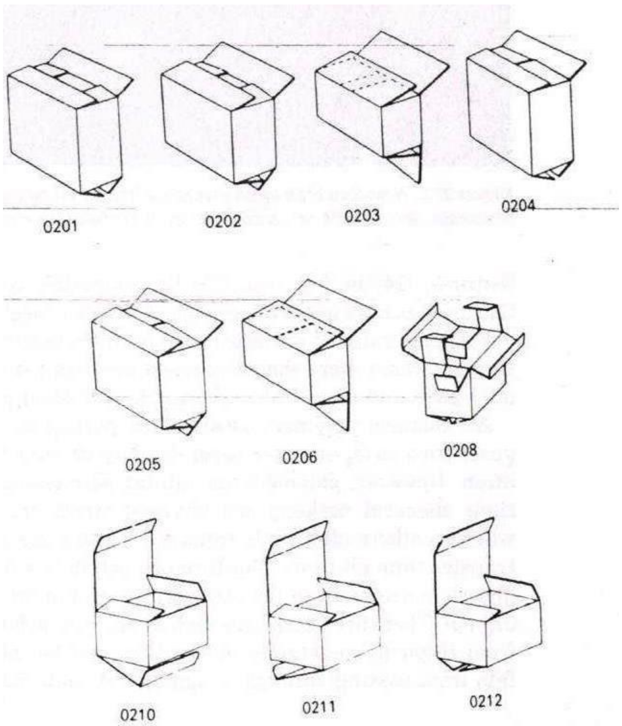
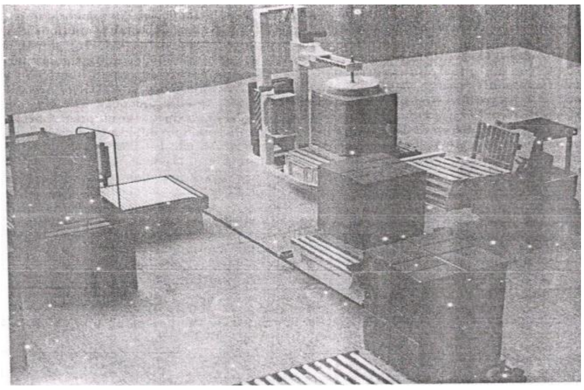


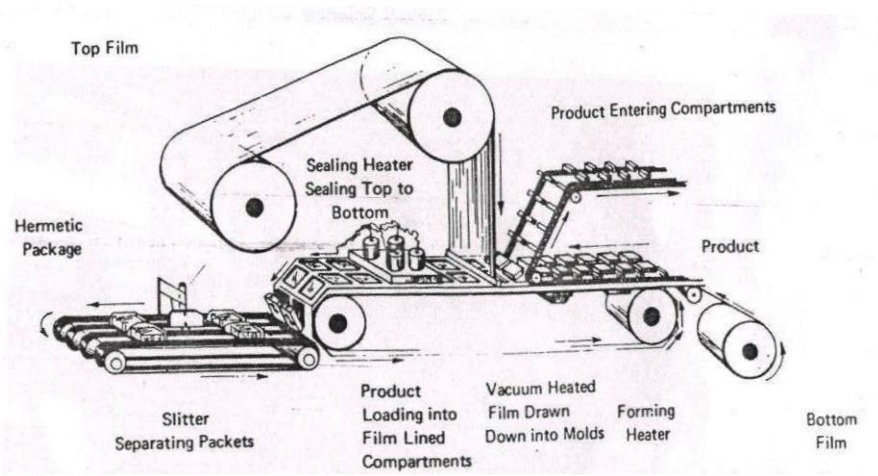
Figure 13.4.3 Some standard designs for secondary corrugated shipping cartons based on international case code 0200. Source: *Paine, The Packaging Media, Blackie& Sons, London, 1977*

Figure 13.4.4 Automated palletizing and rotating stretch wrapping system for stabilizing unit(tertiary) loads prior to removal with a fork lift truck. *Courtesy of Columbia Machine, Inc.*



The filling operation in the food-handling line. This latter approach is called "form- fill-sear and is one of the most efficient ways to package food. Today most flexible containers, whether made from paper, foil, or plastic, are in-line formed, resulting in great savings in handling labor, container transportation costs, and warehouse storage space. Figure 13.4.5 illustrates one common way a roll of flexible packaging material can be formed into a package.

Preforming is illustrated by the can-making machine of Fig. 13.4.6, which may be located in a can-manufacturing facility distant from the food plant. Formed cylindrical cans are shipped with separate can lids. The lids are seamed onto the cans by the food manufacturer after filling. The handling problems and expense are obvious in this type of operation. For this reason many large food companies set up can-making facilities in a building or area close by the can-filling line, and cans are continuously conveyed to the line. The same problems exist with preformed glass



bottles.

Figure 13.4.5 A vacuum form – fill – seal(FFS) process commonly used to package processed meats such as frankfurters, mozzarella cheese, and other products. Such packages may be gas flushed or vacuum drawn. Source: *A.L Brody, Flexible Packging of Foods. CRC Press, Cleveland, OH, 1970.*

One of the earliest in-line packaging operations was the milk carton system in which cartons were assembled from coated fiber flats, filled, and sealed. Although this is still one of the most important in-line packaging processes, it is now being joined by various systems for aseptically packaging previously sterilized liquids. One such system, utiliz¬ing hydrogen peroxide and radiant heat to sterilize heat-sensitive roll-stock material is described later in this chapter. Some of the advanced methods for packaging milk and other liquids in plastic bottles call for the in-line conversion of thermoplastic resins in powder or pellet form into bottles by high-temperature blow-molding techniques, which at the same time heat sterilize the containers. The automatically filled containers are then heat sealed, again taking advantage of the thermofusing properties of the plastic.

13.8.5 Hermetic Closure

The term hermetic refers to a container that is sealed completely against the ingress of gases and vapors. Such a container, as long as it remains intact, will also be impervious to bacteria, yeasts, molds, and dirt from dust and other sources, since all of these agents are considerably larger than gas or water vapor molecules. On the other hand, a container that prevents entry of microorganisms, in many instances, will be nonher-metic; that is, it will allow some gases or vapors to enter. Hermetically sealed containers not only protect the product from moisture gain or loss and oxygen pickup from the atmosphere but are essential for vacuum and pressure packaging.

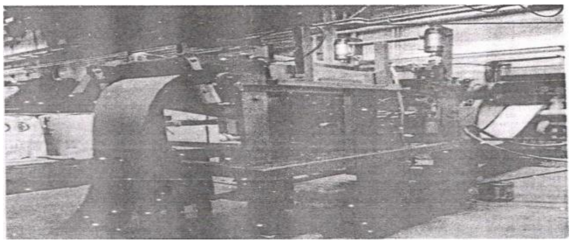


Figure13.4.6 Metal sheets being prepared for can- making of *Coutesy U.S. Stel Corporation*

The most common hermetic containers are rigid metal cans and glass bottles, although faulty closures can make them nonhermetic. With rare exceptions flexible packages are not truly hermetic for one or more of the following reasons: (1) thin flexible films, even when they do not contain minute pinholes, generally are not completely impermeable to gases and water vapor, although the rates of transfer may be exceptionally slow; (2) the seals are sometimes imperfect; and (3) even when film materials are very high barriers to gases and water vapor (e.g., laminants containing aluminumfoil), flexing of packages and pouches can lead to minute pinholes and creases which allow gas and vapor transmission.

13.8.6 Package Testing

Many test procedures exist to measure quantitatively the protective properties of packaging materials and entire containers. These can be divided into chemical and mechanical parameters. Examples of chemical tests are those used to identify plastics, determine if portions migrate to

foods, and measure resistance to greases. Mechanical tests include such things as barrier properties, strength, heat-seal ability, and clarity. The tables in this chapter contain data from several of these tests. Mechanical properties of packaging films (e.g., tensile strength, elongation, tearing strength, bursting strength) are determined on specially designed instruments that precisely measure the forces required to produce these effects. Unfortunately, reporting of test data has lacked standardization and various forms of English and metric units continue to be used. Test data in the tables of this chapter have been kept in their original units, since these remain meaningful to suppliers and users of packaging materials. The packaging industry, however, can be expected to gradually replace many of its present designations with standardized metric units. One of the best sources of methods for testing packaging materials are the publications of the American Society for Testing and Materials (ASTM).

Resistance of packaging films to acids, alkalies, and other solvents can be measured quantitatively by incubating the films in the solvent under controlled conditions and then determining either the degree of leaching of the film into the solvent or changes in the physical properties of the recovered films by some of the methods already mentioned. Resistance of coated metal cans to acid can be estimated by a colorimetric test for dissolved underlying iron in the acid test solution. Resistance of metal cans

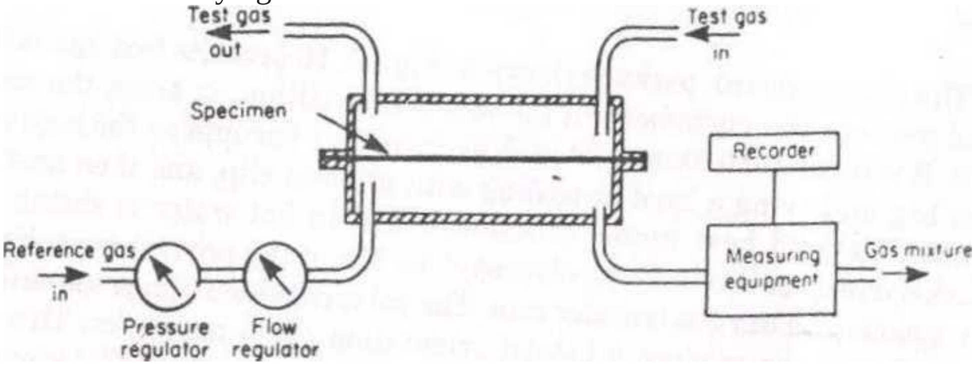


Figure 13.4.7. Method for determining the gas transmission rate (i.e., permeability) of a plastic film (specimen) by measuring the concentration of test gas in a reference gas which is separated from the test gas by the plastic film. Source: F. A. Paine and H. Y.Paine. *Handbook of Food Packaging. Blackie & Sons, London, 1983.*

to acid also can be established in terms of the rate at which hydrogen is given off by the corroding metal.

These are just a few of the approaches used to test package materials. But in the final analysis, although such data permit intelligent initial screening of suitable packaging materials for a particular food application, the final package and product are best evaluated in actual or simulated use tests. This is especially so when the food will receive additional processing (retorting, freezing, etc.) in the final package.

Actual use tests consist of sending limited numbers of food-filled packages through the processing, shipping, warehousing, and merchandising chain where they will be exposed to naturally occurring vibrations, humidities, temperatures, and handling abuses. Such packages are then recovered for analysis. Simulated use tests involve machines and devices for producing physical stresses, and incubation cabinets where

packages can be subjected to various temperature and humidity cycles comparable to what the packaged food will subsequently experience in trade channels. Simulated use test conditions can often be intensified to arrive more quickly at a judgment of package performance.

13.8.7 Packages with Special Features

As pointed out, one of the newer requirements of food packaging is that it help with the product's use. This usually means that the package will have some type of added convenience feature. The "boil-in-bag" package is one of many examples. In addition to protecting the food against microorganisms and dirt, and to a certain degree against moisture and gas transfer, it also is impermeable to grease, nontoxic, compatible with the food, transparent, capable of being evacuated and heat-sealed under vacuum attractive, tamper-evident, easy to open and dispose of, light in weight, requires little storage space, and is low in cost. But this is not all. Its material and seals withstand freezing temperatures and the expansion of foods frozen within it. It then survives frozen storage and the extreme shock of being taken from the home or restaurant freezer and plunged into boiling water for cooking. During boiling, the bag does nor burst from steam or allows boiling water in to dilute the food. All of this is made possible by the exceptional properties of polyester and Nylon films including high tensile strength and stability over a range of temperatures from -73 to 150°C.

13.8.8 Microwave Oven Packaging

One of the most rapidly developing areas of added convenience is packaging designed for the microwave oven (Fig. 13.4.1). Such packaging must meet all other standard



Figure 13.4.8 Cooked and processed meats packaged in shrink films. Many times meats are cooked in the bags in order to retain moisture. Courtesy of Cryoyac Division of W.R Grace.

requirements for food packaging, and also must be transparent to microwaves and able to withstand the temperatures encountered in heating foods in the microwave oven. The most commonly used materials for this application are made of plastics. Several plastics such as polyester and Nylon which are capable of withstanding higher temperatures have been used to package microwave foods. These plastics do not deform or char when exposed to temperatures in excess of 100°C.

One disadvantage of microwave heating is that the heating surface, in this case the package, does not get hot itself. This means that heat is not transferred to the food by conduction and the food does not brown or

otherwise behave like conventionally cooked foods. In order to solve this problem, packaging engineers have constructed high-temperature polymeric packaging materials that contain very small aluminum particles (Fig. 13.4.8). These particles get hot during microwaving, which, in turn, heats the polymer which further heats the food by conduction. These materials are called "susceptors." Susceptors cause foods to brown in a microwave oven. This technology improves the quality of popcorn which is popped in a microwave oven, for example- There are many other examples of innovations resulting from the use of packaging in microwave ovens.

13.8.9 High Barrier Plastic Bottles.

An important development has been the recent introduction of squeezable plastic bottles that have very high barrier properties and aie less than one-fourth the weight of glass, do not break when dropped, and can be incinerated without the production of toxic, corrosive, or noxious compounds beyond those found in burning household or municipal trash. This means that products which required the barrier properties of glass can be packaged in plastic. The reduced breakage of plastic bottles not only benefits consumers but also reduces costs throughout production and shipping channels. Bottle breakage is a frequent cause of complete disruption of filling-line operations. Resistance to breakage also permits use of lighter, less expensive corrugated shipping

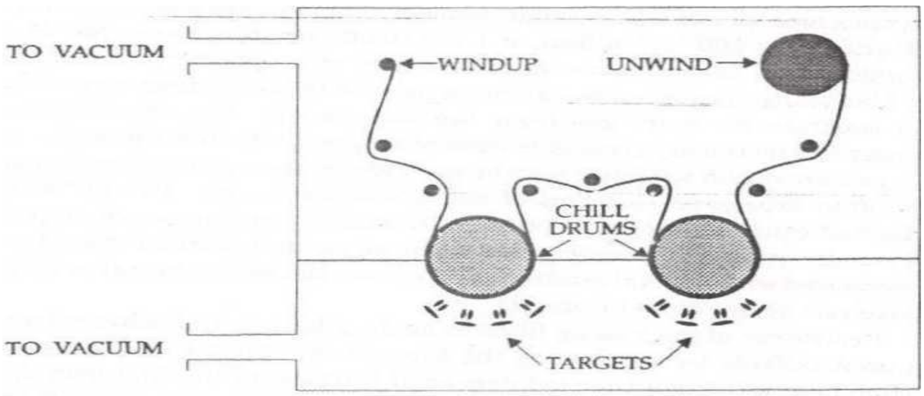


Figure 21.17. Typical manufacturing technology for depositing very small amounts

Figure 13.4.9 Typical manufacturing technology for depositing very small amounts of aluminum on high-temperature plastic films used to heat foods by conduction in a microwave oven. The technique is commonly referred to as "sputtering." Source: G. L. Robertson Food Packaging: Principles and Practice, Marcel Dekker, NY. 1993.

13.8.10 Aseptic Packaging in Composite Cartons.

Another development of worldwide significance has been the composite paper carton which is capable of being sterilized and then aseptically filled with sterile liquid products. This process is called aseptic packaging even though it is both a packaging and processing technology. This technology allows foods such as milk to be packaged in relatively inexpensive flexible containers which do not require refrigeration. This means that milk and juices can be distributed in parts of the world where refrigeration is not common. The packaging material is made from laminated roll stock consisting (from the outside inward) of polyethylene, paper, polyethylene, aluminum foil, polyethylene, and a coating of ionomer

resin. With equipment shown in Fig. 13.8.10, the roll stock enclosed in a cabinet at floor level is drawn upward as a continuous sheet through a hydrogen peroxide bath near the top of the machine. The sheet is passed through squeeze-rollers to remove excess peroxide, and the descending sheet is formed into a tube that is exposed to radiant heat to complete the sterilization and remove traces of peroxide. Next, the tube is further formed into a rectangular shape, end-sealed at package-size intervals, filled with presterilized liquid food, top-sealed, and separated into individual package units in a continuous operation. Commercially sterile liquids have a shelf life of several months at room temperature in the exceptionally lightweight

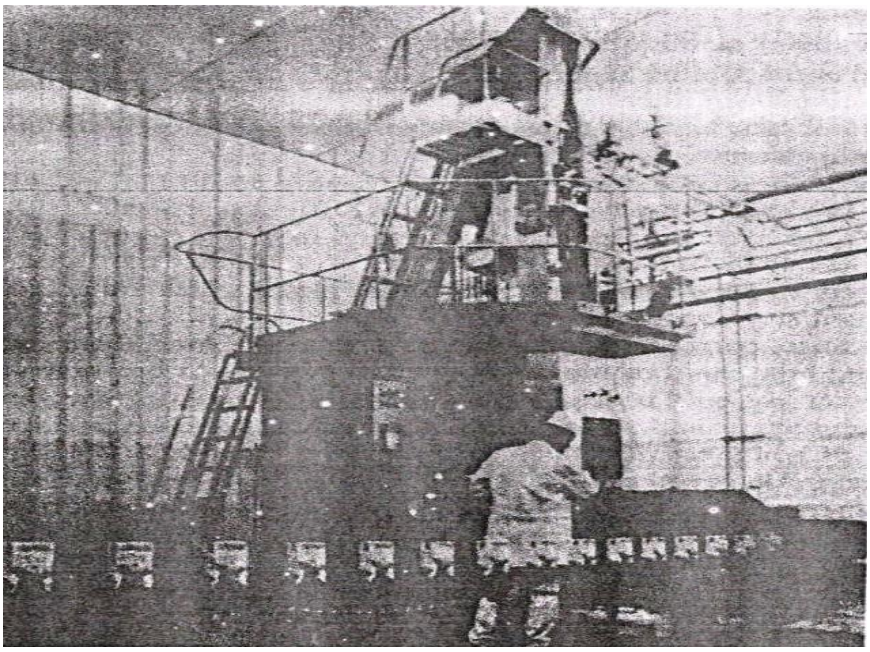


Figure 13.4.10. Aseptic packaging system using form-fill- seal technique. *Courtesy of Tetra Pak. Inc.*

Form-fill-seal package. Several form-fill-seal systems have been developed to take advantage of the rapidly growing aseptic package market.

i) Military Food Packaging

Special packaging problems have always confronted the military. In addition to providing protection, packages that simplify preparation and consumption of the food under adverse circumstances often are required. Thus, one type of military food container is designed with a chemical system separate from the food, which can be made to undergo a rapid exothermic reaction, thus heating the can on opening. It is also possible to design a self-cooling container that might be based on the rapid expansion and release of a compressed refrigerant gas. Such containers presently would be too expensive for general commercial use.

ii) Newer Methods of Cooking and Foodservice

These create special package needs. An example is ovenable paperboard, which is impervious to moisture and fat staining and is heat resistant to 218°C for short periods. These properties, as well as a chinalike gloss, have been obtained by coating paperboard with PET polyester. Such paperboard containers, in the form of serving dishes, are now used for frozen foods to be reconstituted in conventional and microwave ovens.

iii) Packaging and Communication.

The package designer knows that the message conveyed by the package is often the most important single factor that determines a product's sale or rejection. Among details to be considered are the package's color and symbolism. In one's own country errors are less likely to be made, but when packages are designed for distribution in a less familiar region, special care must be taken and the services of a consultant often employed. Pitfalls are many. Purple is an unlucky color to the Chinese and white connotes mourning. The cherry blossom is a favored symbol of the Japanese, but the chrysanthemum, which connotes royalty in Japan, is to be avoided on package labels Further examples applying to Asian markets are listed in Table 21.10. One of the more subtle examples of regional psychology was experienced in Japan where a U.S.- designed tuna fish can pictured a tuna with nose turned down toward the water. When the product did not sell, it was learned that to Japanese a tuna with nose turned down meant a fish that was dead. When the picture of the tuna was modified, sales increased.

iv) Distribution Packaging

Tertiary packaging combines several secondary units or cartons into a single unit for greater efficiency in distribution. The most common unit is usually a full pallet load. Related commercial handling methods involving ship-to-rail, truck-to-air, and other combinations are becoming more sophisticated. The newer methods are not obvious extensions of previous trucking and railroad practices but represent a systems approach to integrating and optimizing packaging, loading, transporting, and un-loading practices for greatest efficiency.

13.8.11 Safety of Food Packaging

i) Migration from Plastics

It is important to know that plastics are not completely inert to foods. Aside from the permeation of gases and vapors, it is also possible that components of the plastic can migrate to the food and would then be consumed with the food. This raises concern for the safety of some plastics. For this reason, all plastics used in food contact mus have specific approval from regulatory agencies for the intended use. Food manufactur ers must get written assurance from the plastic manufacturer that their contair-er wrap meets all requirements for use in food contact.

ii) Contamination

It is primarily packaging which acts as a barrier to contamination of foods. Pre venting recontamination of thermally processed low-acid foods which are stored at room temperature is especially serious. Recontamination with pathogenic bacteria such as Clostridium botulinum can lead to outbreaks of food-borne disease. One examp ® occurred when fish had been processed in defective metal cans which contained sma holes. Several people ended up with botulism, which is often fatal.

Table 13.4.1 Color and Symbolism in Packaging for Asian Markets

Country	Color	Connotation	Symbol	Co nnotation
China	White	Mourning (avoid)	Tigers, lions, & dragons	Strength (use)
Hong Kong	Blue	Unpopular (avoid)	Tigers, lions, & dragons	Strength (use)
India	Green & orange	Good (use)	Cows	Sacred to Hindus (avoid)
Japan	Gold, silver, white, & purple	Luxury & high quality (use);	Cherry blossom	Beauty (use)
	black	use for print only, prefer gay, bright colors.	Chrysanthemum	Royalty (avoid)
Malaysia (population is mixed Malay, Indian, Chinese)	Yellow	Royalty (avoid)	Cows	Sacred to Hindus (avoid)
	Gold	Longevity (use)	Pigs	Unclean to Moslems (avoid)
	Green	Islamic religion (avoid)		
Pakistan	Green & orange	Good (use)	Pigs	Unclean to Moslems (avoid)
Singapore	Red, red & gold, red & white,	Prosperity and happiness (use);	Tortoises	Dirt, evil (avoid)
			Snakes	Poison (avoid)
	red & yellow yellow	Communist (avoid)	Pigs & cows	Same as for India & Pakistan (avoid)
Taiwan	Black	(Avoid)	Elephants	Strength (use)
Thailand			Elephants	National emblem (avoid)
Tahiti	Red, green, gold, silver, and other bright colors	(Use)		
Arab & Moslem States	White	(Avoid)	Animals	(Avoid)
			Pigs	Religious pollution (avoid)
			Star of David	Political (avoid)

SOURCE: Hygrade Products Co., New Zealand.

13.8.12 Environmental Considerations

Packaging of all forms makes up approximately 33% of the disposable solid waste in the United States. Foods use about one-half of all packaging (Fig. 13.4.11). The most common way of disposing of solid waste is land filling. The need to find better ways to dispose of solid municipal waste has prompted interest in both increased recycling food packaging as well as using less packaging in the first place. Neither of these objectives are as simple as they may seem. It is likely that recycled materials wil1 have more chemical and microbiological contaminants than virgin materials. For example, some consumers might use empty plastic bottles to dilute and mix pesticides before recycling the bottle. Traces of the pesticide could remain in the plastic and later enter the food during storage. Recycled paperboard could contain more microbial spores due to contamination.

Another strategy to reduce packaging waste is to use less material when packaging. Figure 13.4.11 Composition of Municipal Waste by Material, 1986 foods.

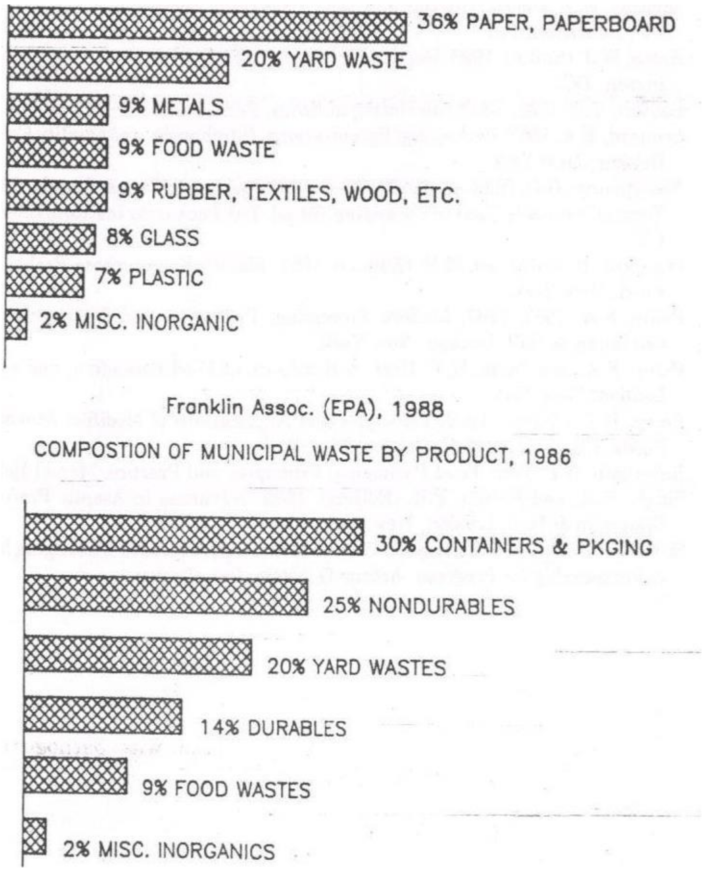


Figure 13.4.11 Composition of solid municipal waste by (A) type of material and (B) by type product. Source: *Based on data from the Environmental Protection Agency,1988.*

This is termed source reduction. However, to do so takes considerable care. Making packages thinner and/or smaller is one approach that has been taken for many products. This reduces the amount of packaging used, but care must be taken so that the package will not break during shipment and allow the food to become contaminated. Making products more concentrated so that they can be packaged into smaller containers is another approach to reducing the amount of packaging used (Fig. 8.4.12). In some cases, extra packaging is used not to protect the foodbut for marketing reasons. In these cases, packaging can be reduced, but food manufactures are concerned that



Figure 13.4.12. Reduction in the amount of packaging used (i.e., source reduction) by making products more concentrated. Both detergent bottles contain the same amount of cleaning power but the smaller bottle is twice as concentrated and hence requires a smaller bottle they will be at a competitive disadvantage if they eliminate packaging which helps sell their products.

Metal and glass containers are recyclable without worry about recontamination, but they are heavy and require considerable energy to transport and melt and, therefore, have their own negative environmental costs. For this reason, lighter-weight plastics or combined plastic, paper, foil containers are sometimes preferred. Another alternative is to incinerate the trash. This too has negative environmental costs. Highly efficient and clean incinerators can be built, but they are expensive. Burning must not produce toxic or otherwise noxious fumes to pollute the air. Innovation in plastics technology holds promise of yielding more plastics that incinerate cleanly. Plastics that can be recycled are another possibility, but the economics of gathering and sorting plastic containers from other trash may limit the feasibility of this approach. Admirable progress continues to be made in the recycling of steel, aluminum, and polyestercontainers. Numerous steel can collection stations have been set up by major steel companies and more are planned. Some municipalities mine steel cans from dumps using magnetic separating equipment before or after garbage incineration and then sell the recovered steel scrap. Major aluminum companies continue to invest heavily in reclamation and recycling. Aluminum has greater scrap value than other components of solid waste, about 10 times that of steel and 15 times that of glass. Collectors bringing aluminum cans to Alcoa reclamation centers receive about $0.50 cents per kilogram for the cans. The Reynolds Metals Co. has been operating a fleet of mobile recycling units in the form of large truck trailers that carry a magnetic separator, electronic scale, and can shredder. The mobile units buy aluminum cans from the public and prepare them for smelting plants. Melting cans to recycle aluminum requires only about 5% of the energy needed to make aluminum from bauxite ore, and the aluminum industry is approaching 70% recycled aluminum in new can production.

Because of its lower economic value and certain other considerations, recycling of glass is not always feasible. One of the largest markets for salvaged glass is in conventional glass-making where crushed waste glass can supply about 30% of the raw materials needed to make new bottles. But such waste glass must be free of food, metal, and other forms of contamination and needs to be color sorted. Where costs for these handling operations are prohibitive, crushed glass of lesser purity can be used by the construction industries in making glass bricks and for admixture with asphalt to pave roads. After incineration to form a partially melted mass, waste glass also is suitable as an undersurface for road construction. With or without crushing and incineration, waste glass can provide useful landfill.

Check your progress - 2
Notes: a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

3. Define Package Testing.
4. write note on High Plastic Bottles.

3. Define Package Testing.

Many test procedures exist to measure quantitatively the protective properties of packaging materials and entire containers. These can be divided into chemical and mechanical parameters. Examples of chemical tests are those used to identify plastics, determine if portions migrate to foods, and measure resistance to greases. Mechanical tests include such things as barrier properties, strength, heat-seal ability, and clarity. The tables in this chapter contain data from several of these tests. Mechanical properties of packaging films (e.g., tensile strength, elongation, tearing strength, bursting strength) are determined on specially designed instruments that precisely measure the forces required to produce these effects. Unfortunately, reporting of test data has lacked standardization and various forms of English and metric units continue to be used. Test data in the tables of this chapter have been kept in their original units, since these remain meaningful to suppliers and users of packaging materials. The packaging industry, however, can be expected to gradually replace many of its present designations with standardized metric units. One of the best sources of methods for testing packaging materials are the publications of the American Society for Testing and Materials (ASTM).

Water vapor transmission rates (WVTR) can be measured by sealing sheets and films across the opening of a vessel that contains a weighed quantity of a desiccant material. The vessel is then placed in an atmosphere of controlled temperature and humidity. Periodic weighing of the container of desiccant to determine water pickup gives a measure of water vapor transfer. This measure is commonly expressed in terms of grams per 100 in. 2 of film, of 1 mil (0.001 in.) thickness, per 24 h under the defined conditions of temperature, humidity, and atmospheric pressure.
Gas transmission rates can be measured by an instrument which uses the test film to separate an inert gas from the test gas(es). The instrument then continuously measures increase in concentration of oxygen in the inert gas (Fig.13.4.7). Transfer rates of specific gases such as oxygen, carbon dioxide, or nitrogen can be measured with special electrodes fitted into the sealed vessel or by gas chromatographic analysis of the vessel contents.

Resistance of packaging films to acids, alkalies, and other solvents can be measured quantitatively by incubating the films in the solvent under controlled conditions and then determining either the degree of leaching of the film into the solvent or changes in the physical properties of the recovered films by some of the methods already mentioned. Resistance of coated metal cans to acid can be estimated by a colorimetric test for

dissolved underlying iron in the acid test solution. Resistance of metal cans

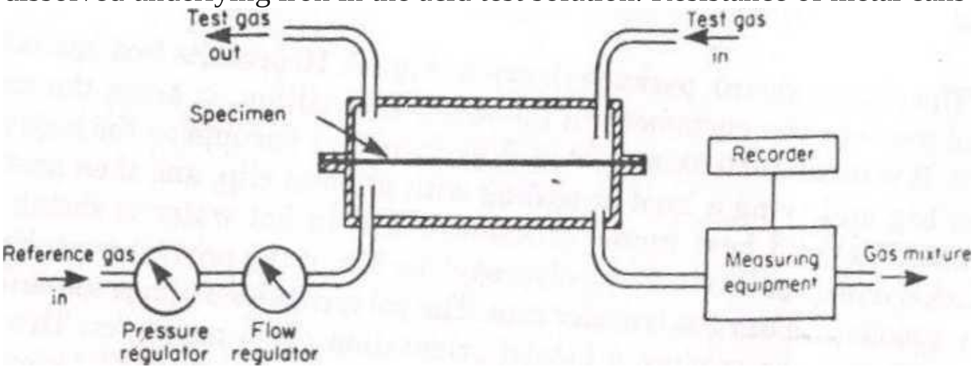


Figure 13.4.7. Method for determining the gas transmission rate (i.e., permeability) of a plastic film (specimen) by measuring the concentration of test gas in a reference gas which is separated from the test gas by the plastic film. Source: F. A. Paine and H. Y.Paine. *Handbook of Food Packaging. Blackie & Sons, London, 1983.*

to acid also can be established in terms of the rate at which hydrogen is given off by the corroding metal.

4. Write note on High Plastic Bottles.

An important development has been the recent introduction of squeezable plastic bottles that have very high barrier properties and aie less than one-fourth the weight of glass, do not break when dropped, and can be incinerated without the production of toxic, corrosive, or noxious compounds beyond those found in burning household or municipal trash. This means that products which required the barrier properties of glass can be packaged in plastic. The reduced breakage of plastic bottles not only benefits consumers but also reduces costs throughout production and shipping channels. Bottle breakage is a frequent cause of complete disruption of filling-line operations. Resistance to breakage also permits use of lighter, less expensive corrugated shipping

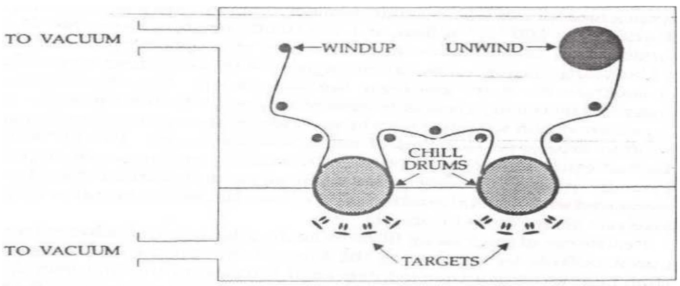


Figure 21.17. Typical manufacturing technology for depositing very small amounts

Figure 13.4.8 Typical manufacturing technology for depositing very small amounts of aluminum on high-temperature plastic films used to heat foods by conduction in a microwave oven. The technique is commonly referred to as "sputtering." Source: G. L. Robertson Food Packaging: Principles and Practice, Marcel Dekker, NY. 1993.

13.5 Bar coding – Nutrition labeling and nutrition claims, coding of food products

13.5.1 Canning and Bottling of Fruits and Vegetables

The sealed cans are placed in the cookers, keeping the level of water 2.5 to 5.0 cm above the top of the cans. The cover of the cooker is then screwed down tightly and the cooker heated to the desired temperature. The period of sterilization (processing) should be counted from the time the water starts boiling. After heating for the required period the cooker is removed from the fire and the petcock is opened. When the pressure comes down to zero thecover is removed and the cans are taken out.

1) Cooling

After processing, the cans are cooled rapidly to about 39°C to stop the cooking process and to prevent stack-burning. Cooling is done by the following methods:

a) dipping or immersing the hot cans in tanks containing cold water;
b) letting cold water into the pressure cooker specially in case of vegetables;
c) Spraying cans with jets of cold water; and
d) exposing the cans to air.

Generally the first method, i.e., dipping the cans in cold water, is used. If canned products are not cooled immediately after processing, peaches and pears become dark in colour, tomatoes turn brownish and bitter in taste, peas become pulpy with cooked taste and many vegetables develop flat sour (become sour).

2) Storage

After labelling the cans, they should be packed in strong wooden cases or corrugated cardboard cartons and stored in a cool and dry place. The outer surface of the cans should be dry as even small traces of moisture sometimes induce rusting. Storage of cans at high temperature should be avoided, as it shortens the shelf-life of the product and often leads to the formation of hydrogen swell.

13.5.2 Containers for packing of canned products

Both tin and glass containers are used in the canning industry, but tin containers are preferred.

(1) Tin containers

Tin cans are made of thin steel plate of low carbon content, lightly coated on both sides with tin metal: It is difficult to coat the steel plate uniformly and during the process of manufacture small microscopic spots are always left uncoated, although the coating may appear perfect to the eye. The contents of the can may react with these uncoated spots resulting in discoloration of the product or corrosion of the tin plate. When the corrosion is severe, black stains of iron sulphide are produced. It is necessary, therefore, to coat the inside of the can with some material (lacquer) which prevents discoloration but does not affect the flavour or wholesomeness of the contents. This process is known as "lacquering".

Two types of lacquers are used :

(i) Acid-resistant: Acid-resistant lacquer is golden coloured enamel and cans coated with it are called R-enamel or A.R. cans. These cans are used for packing acid fruits which are of two kinds : (a) those whose colouring

matter is insoluble in water, e.g., peach, pineapple, apricot, grapefruit, and (b) those in which it is water-soluble, e.g., raspberry, strawberry, red plum and coloured grape. Fruits of group (a) are packed in plaincans and those of group (b) in lacquered cans.

(**ii) Sulphur-resistant**: This lacquer is also of a golden colour and cans coated with it are called C-enamel or S.R. cans. They are meant for non-acid foods only and should not be used for any highly acid product as acid eats into the lacquer. These cans are used for pea, corn, lima bean, red kidney bean., etc.

Table 13.5.1 Size of cans: The sizes of cans in general use are given below:

Trade name of can	Size (mm)
A1	68x102
1- lbJam	78x90
AI – T	78x119
A2	87x114
1-lb Butter	103x70
A21b Jam	103x102
A21/2	103x119
7-lb Jam	157x148
A10	157x178

Recently, a midget can has become highly popular for fruit juices, mango nectar, etc. It holds about 165 ml of beverage and is a very popular picnic pack.

Tin containers are preferred to glass containers because of certain advantages:

i. ease of fabrication,
ii. strength to withstand processing,
iii. light weight,
iv. ease in handling,
v. cheapness, and
vi. can be handled by high speed machines.

(2) Glass containers

Glass containers possess two distinct advantages over tin cans: (i) the contents being visible can be easily displayed, and (ii) they can be used over and over again. Moreover, glass of high quality does not contaminate the contents. Hence, such containers are preferred for packing baby food, but being fragile require extra care during handling and processing.

In recent years, plastic containers and heat-sealable pouches have been successfully tried in various research and development laboratories as possible substitutes for tin and glass containers.

a) Canning of fruits (and tomatoes)

The general process of canning has been discussed earlier. Large spoons, peeling and coring knives, aluminium or stainless steel pans of large size, sanitary cans, thermometer, hand refractometer, measuring cylinder and can sealing machine, etc., are generally required. The specific requirements of syrup strength, exhausting, processing temperature and time, and type of

cans, etc., for canning of various fruits are given in the table entitled 'specific requirements for canning of fruits and tomatoes.'

b) Bottling of fruits

Bottles have proved to be very good containers for home preservation of fruits. Although their initial cost is high, they can be used several times and last for many years if carefully handled. The fruits look attractive through the glass and do not develop metallic flavour. Bottling does not need a sealing machine but is not suitable from the manufacturer's point of view as the initial capital required is high. Cans are cheaper, quite handy and lighter and loss due to breakage is less. Hence on commercial scale, tin cans are preferred to glass jars or bottles.

The water should be free from contamination. If necessary, it should be chlorinated. Any good drinking water supply is suitable for canning, provided it is not unduly hard.

3) Disposal of cannery waste

A large quantity of waste is produced by a cannery, containing a high percentage of solid matter, such as skins, peels and colloidal starchy material. Hence the cannery should be situated at such a place where waste could also be profitably utilized to make by-products.

4) Transport facilities

The problems of transport in India have already been dealt with in the third chapter, i.e., "Scope of Fruit and Vegetable Preservation in India", and need not be discussed here. However, it is essential that the cannery should be situated near a road which connects it important towns in that area.

13.5.3 Causes of spoilage of canned foods

Spoilage of canned products may be due to two reasons:

1. Physical and chemical changes, and
2. Microorganisms.

(A) Spoilage due to physical and chemical changes

(1) Swell : When the ends of an apparently normal and perfect can with good vacuum become bulged it is termed as 'Swell or 'Blower'. The bulge is due to the positive internal, pressure of gases formed by microbial or chemical action.

i) Hydrogen swell : This type of bulging is due to the hydrogen gas produced by the action of food acids on the metal of the can. The bulging ranges from 'Flipping—to the 'Hard Swell'. The food generally remains free of harmful microorganisms and is fit for consumption.

ii) Flipper : The can appears normal, but when struck against a tabletop one or both ends become convex and springs or flips out, but can be pushed back to normal condition by a little pressure. Such a can is termed as "flipper" and may be an initial stage of swell or hydrogen swell. It may also be caused by overfilling, under-exhausting or gas pres¬sure due to spoilage.

iii) Springer : A mild swell at one or both ends of a can is called a 'springer'
which may be an initial stage of hydrogen swell or be due to insufficient exhausting or overfilling of the can. The bulged ends (or at least one end) can be pressed back to the original position, but will again become convex after some time.

iv) Soft swell : At a more advanced stage, swell develops at both ends of the can which can be pressed and returned to normal position, but springs back when the pressure is removed. A swell of this type is termed as "soft swell" and is more or less similar to that of flipper.

v) Hard swell: This is the final stage of swell. The bulged ends cannot be pressed back to normal position and the cans ultimately burst.

The following precautions are necessary to prevent the formation of hydro-swells:

a) Good quality tin plate should be used for making the cans. The quality is related to the porosity of the tin coating. The greater the porosity, the greater is the possibility of corrosion of the can. The porosity can, however, be decreased by increasing the thickness of the coating and making it more uniform. Plain cans are less susceptible to hydrogen swell formation than lacquered cans.
b) About 0.5 per cent citric acid should be added to the syrup used for canning fruits of low acidity such as cherry, mango, papaya, etc. Citric acid checks the formation of hydrogen swell to a great extent.
c) Before placing the lid a head space of 0.6 to 0.9 cm should be left in the can which is to be exhausted.
d) The lid should be placed firmly or clinched before exhausting to ensure a high vacuum in the can.
e) Cans should be exhausted for a fairly long time, but without affecting the quantity of the product unduly. The larger the quantity of oxygen remaining in the can, the greater would be the corrosion because oxygen combines with the nascent hy-drogen formed by the action of acid cn the tin container. In the absence of air, the rate of corrosion is low. Oxygen can be excluded from the can by filling it properly and exhausting it thoroughly.
f) The sealing temperature should not be below 74°C.
g) At high storage temperature hydrogen formation will be more.

resulting finally in swell, hence canned products should be stored under cool and dry conditions.

2. Overfilling: Spoilage due to overfilling is common. During retorting, over-filled cans become strained due to expansion of the contents, and in the absence of vacuum in them swelling takes place. If the cans are properly heat exhausted, the excess material overflows from it due to expansion and thus spoilage because of overfilling is avoided.

3. **Faulty retort operation**: When the steam pressure is reduced rapidly at the end of processing, high pressure develops inside the cans resulting in their distortion and the cans when cooled look like "swells". Cans of very thin tin plate should not be used as they cannot withstand the pressure which develops in the cans while processing.
4. **Under-exhausting :** Cans are exhausted to remove most of the air. This helps in the proper filling of fruits and vegetables and also creates a good vacuum, which is necessary to accommodate any pressure that might develop inside the can as a result of production of hydrogen due to corrosion.Improperly exhausted cans may suffer

severe strain during heat processing due to the large internal pressure of the gas present in it. Under-exhausted cans show strain ranging from slight flipping to distortion, depending upon the amount of gas evolved from the product and the size of the head space.

5. **Panelling** : It is generally seen in large sized cans that the body is pushed inward due to the high vacuum inside. This also occurs when the tin plate is thin or the cans are pressure cooled at very high pressure. In very severe cases, seam leakage may occur but normally this is not regarded as spoilage.
6. **Rust :** Cans having external rust must be thoroughly examined after removing the rust and, if the walls show a pitted appearance, should be rejected as spoiled. Cans slightly affected by rust if not used immediately should be rejected. Rust is mostly seen under the label and subsequently affects the label as well. Rust formation can be checked if the cans are externally lacquered.
7. **Foreign flavours** : During preparation, filling, storage or even transporta-tion, conditions may become unhygienic and the products may develop foreign or "off-flavours". If unsuitable metallic containers are used, a "metallic flavour" develops. Flavour is an important characteristic for maintaining which packages must be examined at regular intervals.
8. **Damage** : Rough handling of cans due to carelessness or ignorance may damage them. If any cans show signs of leakage or severe distortion they must be rejected.
9. **Undesirable texture** : Texture is another important characteristic, like flavour and colour, which is detected easily by a consumer. In order to maintain the standard of a product its texture should be tested periodically. Although there are no precise parameters for measuring texture, an instrument like "Tenderometer", which measures the resistance to shearing and relative tenderness, can be used for peas and beans:

   Calcium salts present in the water used for canning have a "toughening effect" on peas and beans, but such hardening is considered desirable for potatoes and tomatoes.

   Care should be taken that the processing of soft fruits does not result in their becoming-pulp.
10. **Corrosion of cans :** Cans become corroded or perforated due to the acidity of the contents, specially highly acid fruits. In recent years, attempts have been made to reduce the spoilage by using improved lacquers for internal coating of cans.
11. **Leakage** : A leaking can is known as a "Leaker". This may be due to: (i) defective seaming, (ii) nail holes caused by faulty nailing of cases while packing, (iii) excessive internal pressure due to microbial spoilage sufficient to burst the can, (iv) internal or external corrosion, and (v) mechanical dam¬age during handling.
12. **Breathing :** There may be a very tiny leak in the can through which air can pass in and destroy the vacuum. In such cases the food is damaged due to rusting of the can caused by oxygen in the air but still remains fit for con-sumption.

13. **Bursting** : This may be caused by the excess pressure of gases produced by decomposition of the food by microorganisms, or by hydrogen gas formed by the chemical action of food acids on the tin plate. In such cases the canned product cannot be used.

13.5.4 Plastics in Food Industry

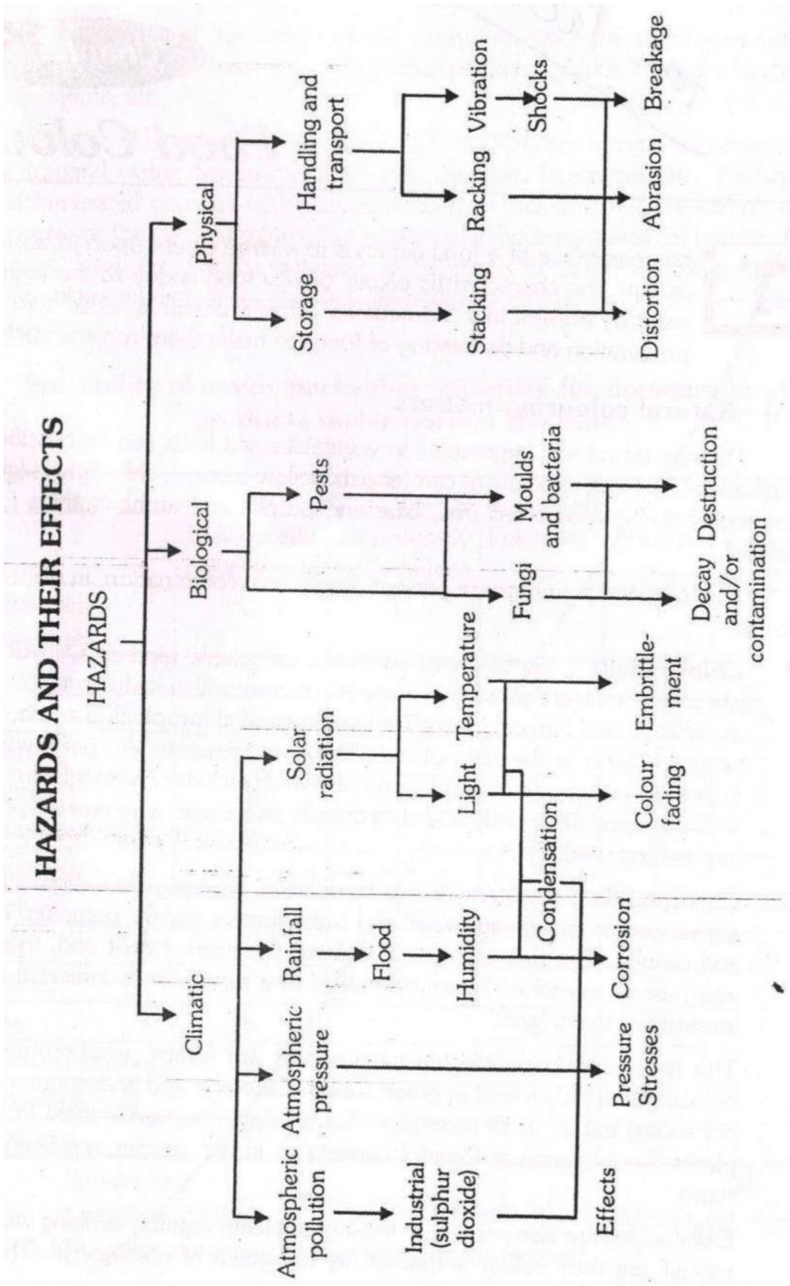
Advantages of plastics for packaging

1. Plastic packages are pilfer-proof, temper-proof, break-resistant, corrosion- resistant and leak proof.
2. Plastic can be processed into any desired shape or form, such as films, sheets, bottles, tubes, pouches, crates, etc.
3. Plastic packages do not pose any major disposal problem or environmental hazard, since almost all plastics can be recycled for reuse.
4. Plastics are light and less bulky than other packaging materials, which results in saving in cost of storage and transportation.
5. Some new plastics have excellent barrier properties to moisture, odour, oxy¬gen and other gases so that the desired shelf-life of various products can be maintained.
6. They are resistant to most chemicals, non-toxic in nature and absolutely safe to use even in direct contact with food products, medicines, etc.
7. They can be sterilized by all conventional methods.

13.5.5 Hazards of plastic packaging

Packaging materials, packages and packaged products are liable to several hazards during storage and transportation, the most common ones being:

A. **Static hazards**: These occur because of compression of goods due to stacking and are influenced by the nature of goods, duration of stacking, condition of floor such as evenness and stacking pattern.
B. **Mechanical hazards:** Uneven lifting due to bad slinging, dropping of __package and piercing, puncturing or tearing by hooks, straps, nails,etc., are the major examples.
C. **Transport hazards**: These are vibration and bouncing particularly because of bad roads, shunting shocks, crushing by ropes used for tying, side impacts-due to sudden braking and dropping of packages during loading or unloading.
D. **Climatic hazards:** The major hazards are exposure to direct sunlight, rain water, temperature and humidity variations and environmental pollutant gases.
E. **Miscellaneous hazards:** These are :
    1. Some corrosive gases may cause stress-cracking.
    2. Biological hazards, such as bacteria, fungi, rats, etc.
    3. Contamination by other products stored alongside which may have leaked.
    4. Fire



Table

13.5.5.1Hazards and their effects

13.5.6 Limitations

Plastic packages have certain limitations also, which are :

1.They are not a total barrier to gases and water vapour, although some new barrier plastics have greatly improved oxygen, gas and odour impermeability.

2. When stretched PVC/PET is used instead of giass for bottles, consumers may get the impression that there is less quantity of product because of reduced thickness.

3 .Abrasion resistance is not always adequate.

4. Some chemicals do attack particular plastics.

13.5.7 Packaging and labelling of foods

Packaging

Is an and science. Packaging is an art of presenting a product. Scientific and technological advances have brought revolutionary change

in packaging. About 40 years ago, when people set out to buy provisions, they used to carry bottles or vessels or gunny bags. But now, neatly packed branded grocery items are available in departmental stores. Packaging as distinct from mere packing plays its most visible and catalytic role in a modern economy.

Functions

A product whether it is factory made or farm produce has to reach its destination, the ultimate consumer in the same condition without any deviation from the original characteristics, one requires packaging.

Nature's own packaging~Ts unique. Nature has packaged a banana pomegranate, an ear of corn, coconut, etc. Due to good packaging methods, products are marketed over larger areas. Foreign prod¬ucts are easily available in the Indian market due to packaging.

Packaging serves 3 major functions—protection, preservation and promotion.

Protection of the product can be from climatic hazards and mechanical hazards. Climatic hazards would include atmospheric moisture, oxygen, light, heat, cold and microbial attack. The presence of water vapour and air give rise to rancidity development (due to oxidation). In foods containing meats or prepared with fat (fried foods) vacuum or nitrogen or carbon dioxide packing have been successful in delaying or inhibiting the spoilage condition. Some of the snack foods like potato wafers sold in pillow packs are gas packed to prevent rancidity. If the gas is let out rancidity occurs. It stops foreign bodies getting in. Mechanical hazards are those happening during packing, storing, transportation and distribution and in the form of impacts, vibrations and compressions.

Product preservation means the extent of time a product could be preserved in a packaging system. The product should maintain the quality till it is consumed. The better the packing the better the preservation of the qualities of the product. It keeps oxygen out and prevent food from going stale. Proper intact packing is an assurance of guarantee of the product quality, prevents tampering andinfuses confidence in the customer thus prevents spurious items and cheap imitations. Customer gets convinced about the authenticity of the commodity. Today, biscuits stay cractding fresh months on end and cakes retain their softness even after weeks due to tough cellophane package.

Classification

Unit pack: It is also called primary pack or consumer pack and the consumer receives the product in that pack. The size and number of units going into each pack depends on the nature of the product and the merchandising method.

Intermediate pack: Also called secondary pack, the purpose of the intermediate pack can be utilisation of couple of unit packs, distribution, requirement, display value etc.

Bulk pack: Master pack, distribution pack, transport pack all refer to bulk pack only. This pack is used for distribution of unit packs or intermediate packs. In general the bulk pack has to take care of protection against mechanical hazards.

13.5.8 Materials used for packing

The conventional methods of packing which are prevalent even now to a large extent are tin or aluminium containers, glass bottles and jars, paper and waxed paper wrappings, paper cartons, card¬board and certain plastic containers. Tin and aluminium containers have become costly. The complex nature of a food product demands a judicious selection of the packaging material and the method of marketing decides the package form. Depending upon the nature of the product, it has to be protected against various physico-chemical factors. Continued use of paper in increased volume dwindles the natural resources. Packaging of food depends on physical characteristics, chemical composition and shelf life.

Dehydrated and moisture sensitive products are to be protected against moisture gain. Fatty products like fried foods, nuts, edible oils etc. tend to become rancid due to oxidation of fats. In the former case, materials with good water vapour barrier properties are to be used whereas in latter case, materials with low oxygen permeability are suitable. Products like butter, tea. Chocolates, spices tend to pick-up foreign odours and thus should be protected by the use of materials which do not impart any taint to these products and also gives protection against ingress of odour from outer sources.

A variety of packaging materials are used by the processed food industry. Materials are rigid, semi-rigid and flexible..

Rigid materials - glass bottles, tin containers, aluminum containers.

Semi rigid type- plastic bottles, thermoformed containers, lined carton, coated and laminated carton.

Flexible type - Wrappers, pouches, stand-up pouches, laminates, films.

Class containers: Glass containers may be in the form of bottles, jars, tumblers etc. In spite of its heaviness and fragility, glass is still predominantly used as a packaging medium for a number.

13.5.9 Points to be considered before designing a packaging system

Product details: Physical state, weight, size, chemical composition, vulnerability to environment and fragility.

Distribution: Method of distribution either by road, rail, sea, air or combination of two or three modes.

Handling: Cargo handling, manually or mechanical means.

Destination market: In the case of export market, the details regarding the importing country's laws and regulations.

Packaging cost: Details of material cost, storage cost, packaging operational cost, distribution cost, insurance cost and development cost.

13.5.10 Laws related to packaging

When the products are sold in repack condition, the consumers are not in a position to find out anything about the contents of the package as well as the quantity and other factors. The Central Government set up an expert committee in the year 1966 to review the law relating to Weights and Measures, and the consequent draft legislation introduced elaborate provisions in respect of packaged commodities. Standard of Weights and Measures (package commodities) rules was introduced in 1977.

Any person who wants to repack any commodity for sale or distribution or delivery can do so only in standard quantity specified in relation to such

commodity. For example, bread can be sold only in quantities of 100, 200, 400, 800 and 1200 g.

Packaging and labelling of foods

1. No person shall manufacture, distribute, sell or expose for sale or despatch or deliver to any agent or any agent or broker for the purpose of sale, any packaged food products which are not marked and labelled in the manner as may be specified by regulations:
   Provided that the labels shall not contain any statement, claim, design or device which is false or misleading in any particular concerning the food products contained in the package or concerning the quantity or the nutritive value implying medicinal or therapeutic claims or in relation to the place of origin of the said food products.

Every package shall have thereon or on a label securely affixed thereto a declaration as to

- The name and address of the manufacturer or if the manufacturer is not the packer the name and address of the packer with written consent of the manufacturer.
- The common or generic name of the commodity contained In the package.
- Net quantity in terms of standard unit or weight or measure or if sold by number, the number of the commodity contained in the package.
- The month and the year in which the commodity is manufactured or repacked.
- The retail sale price which is maximum price at which the commodity in pack form may be sold to the ultimate consumer inclusive of taxes.
- If sizes are relevant, dimensions of the commodity contained in the package.

In the case of any bottle containing milk, soft drinks, ready to serve fruit beverages which are returnable by the consumer for being refilled, the month and year declaration need not be given. In the case of package containing vegetables, fruit or liquid milk in pouches, month and year declaration need not be given. Sale price is not required to be mentioned for any uncanned package of vegeta¬bles, fruits, fish, meat, bottle containing liquid milk.

Every wholesale package shall bear thereon

1. The name and address of the manufacturer or if the manufacturer is not the packer, the name and address of the packer.
2. The identity of the commodity contained.
3. The total number of retail packages obtained in such wholesale package.

An export package shall indicate that

1. it is intended for export
2. the identity of the commodity and the net weight, measure of such commodity.
3. the name and address of the manufacturer.

An export package shall not be sold in India unless the manufacturer or packer has repacked the commodity in accordance with the rules applicable for retail packages.

In spite of all the advantages of packaging there is a small risk for the consumer as he cannot find quality and quantity of the food that is packed.'Better quality of life through 'better packaging' in the slogan of the World Packaging Organisation. This sums up the important place that packaging occupies in the modem economy.

13.5.11 Nutrition labelling

The food industry contributes to nutrition education by offering products that correspond to the current needs of consumers and by informing them of product ingredients and nutritional characteristics.

Nutrition labelling refers to the standardised presentation of nutrient content of the food.

Generally the claims fall into some broad categories.

- **Nutrition claims:** They can be categorised as representations which state, suggest or imply that a food has particular nutritional properties including energy value, content of protein, fat, carbohydrates, vitamins and minerals. List of ingredients and mandatory declaration of certain nutrients cannot be treated as a nutrition claim.
- **Nutrient content claims:** This is a nutrition claim that describes the level of a nutrient contained in a food e.g., low in fat or iron rich or low sodium.
- **Comparative claim:** It is a claim that compares the nutrient levels or energy value of two or more foods. The foods being compared should be different versions of the same food or similar food. The difference in nutrient content and energy value should be given.
- **Nutrient function claim:** This is a claim that describes the physiological role of a nutrient in the growth, development and normal function of the body e.g., contains calcium for stronger teeth.

In India, the idea of bringing out specific laws for nutrition labelling is under active consideration. As of now, it is not mandatory for processed foods in general, except for rules 32A, 37B and 37D of the Food Safety and Standards Act. Rule 37A states that a food claimed to be enriched with nutrients shall give the quantities on the labels. Rule 37D refers to health claim benefits of the oils. In the absence of adequate laws, misconception exists among our population about the authenticity of nutrient claims on food labels. The processed foods for which requirements are stringent are infant milk substitutes and foods claiming curing or preventing diseases.

The labels should legibly bear all ingredients and quantities used. Health Food supplements should not depict any diagram, picture or photograph suggestive of medicinal or disease specific claims.

13.5.12 Guiding principles of nutrition labelling

- To make nutrition labelling useful, available and accessible to consumers. At the same time, they should be clear, simple, accurate, practical, readable, informative, consistent and legible.
- To devise a practical 'nutrition label'. The nutrient content per serving or per 100 g/100 ml. And serving size should be realistic.
- The government in this scenario has to consider enacting some guidelines at the earliest, which should not throttle the process of

giving information on labels as displaying properly supported health claims in one way of creating consumer awareness and education.

13.5.13 Codex guidelines

Codex Commission adopted International Guidelines on Nutrition Labelling in 1985. ilic use ot nutrition labelling is voluntary except when a nutrition claim is made. The codex core list includes energy, protein, fat and carbohydrate content. The declaration of other nutrients is permitted or required depending upon claims. In addition, a country may require the declaration ot nutrients in the interest of the health of its population.

Under the codex guidelines, nutrition labelling is intended to inform consumers about the nutritional content of foods, in combination with education efforts, promote wise food choices. Nutrient labelling provides a means for conveying information on the nutrient content of a food. It is also intended to encourage manufacturers to formulated nutritious foods in line with dietary recommendations.

13.5.14 Labelling provisions in existing food laws

The Food Safety and Standards Act, 2006.

Under this Act every package of food shall carry a label giving the following information:

- The name, trade name or description of food contained in the package.
- The names of ingredients used in the product in descending order of their composition by weight or by volume as the case may be.
- In case both colour and flavours are used in the product, the label should mention.
- If gelatin is used as an ingredient, a declaration should be made using the words "gelatin - animal origin".
- A label should not contain any statement, claim, design, device, fancy name or abbreviation which is false or misleading in any particular way, concerning the food contained in the pack¬age or concerning the quality or the nutritive value or in relation to the place or origin of the food.
- Labelling of pre-packed irradiated foods should be in accordance with the provisions of rule 32 and 42 of the food safety and standards Act.
- The package, label or advertisements of edible oils and fats should not use expressions like 'super-refined', 'extra-refined', 'micro refined' 'double refined', 'ultra refined', 'anti cholesterol', 'soothing to heart' or 'saturate' and 'fat free'.
- The Act also makes it mandatory that labels should not use words implying recommendations by medical profession.

The edible oils should be packed in a container and marked and labelled in manner specified in the Act. The container's label should necessarily have the brand name, name and address of the packer, description of contents, net mass/volume, batch number, month and year of manufacture.

Labels of the containers should have

- ❖ Name of the product, date of manufacture, net weight/volume, name and address of the manufacturer.
- ❖ Unauthorised use of words, pictures etc., showing imitation is prohibited.
- ❖ Every package which contains monosodium glutamate shall bear the label saying "This package contains monosodium glutamate. Unfit for infants below 12 months".
- ❖ List of any permitted preservatives and additives added.
- ❖ Licence number and category.
- ❖ List of poisonous metals such as lead, copper, arsenic, pesticides, sequestering and buffering agents. It has to be ensured that no meat product shall contain MSG in excess of percent by weight.

The producers should comply with all packing and labelling requirements recommended under the order.

13.5.15 Compulsory 'Best Before' date

Government has made it mandatory with effect from July 1999 that all packed food items should necessarily display 'Best Before' date.

It has been made mandatory that every container of milk substitute or infant food or any label affixed there to shall indicate in a clear conspicuous and easily readable manner an important notice which reads, "Mother's milk is best for babies" in capitals.

13.5.16 labelling genetically modified foods

An international labelling standard for GM foods is being developed under ihe auspices of the Codex Committee on Food Labelling (CCFL). In the Indian context in November 2000, the Ministry of Agriculture announced that genetically engineered seeds and food would not be allowed into the countryuntil their safety was scientifically proved. Currently it is illegal to import, store, manufacture or sell any GM food in India.

13.5.17 Marketing the 'Animal Origin' foods

Recently, the Government of India made a major amendment to the Food Safety and Standards Act by introducing the labelling of vegetarian and non- vegetarian foods.

From October 4, 2001, it has become mandatory for all packaged foods containing ingredients of animal origin to sport a browr. dot encased in a brown box. As of now, milk and milk products, if they are used as ingredients are exempted from this order. This rule would also apply to pharmaceutical companies, which produce biopharmaceuticals and nutritional supplements derived from animal sources. For vegetarian foods, the label should have green dot encased in a green box.

13.5.18 Labelling nutraceuticals

Now that there is no well-defined regulation guiding the labelling of these products, they have to usually follow the labelling requirements under the FSS Act. The questions relating to functional foods, dietary supplements and their tall claims about nutrient benefits still continue today the policy makers.

The current laws sometimes fall too inadequate to look into various health claims that are being made by the packed food manufacturers. There will be growing pressures on the government to come up with definite food labelling laws so that the makers do not make misleading claims.

After detailed deliberation on a number of issues, the Ministry of Health recommended that some measures/modalities, which might be adopted to regulate the products marketed for so called health benefits.

Health supplements is a product that

- ❖ Is not represented for use as a conventional food for the sole item of meal or diet.
- ❖ Which does not claim to prevent, cure or mitigate any specific disease except for certain health benefit/promotion claims as may be permitted.
- ❖ Is intended for insertion in the form of powder, tablet, capsule, soft gel or liquid.
- ❖ Is intended to supplement the diet like vitamins, minerals, herbs, amino acids and/or concentrate metabolite extract.

It has also been made mandatory that the name of such products should not be suggestive.

Surveys have indicated that Indian consumers rarely looked at the nutrition labels and the same labels do not influence their decision about product selection. They also did not understand the labels.

Nutrition education is required in this regard on top priority.

Check your progress - 3
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.

5. what are the causes of spoilage of canned foods?
6. Write any five advantages of plastic for packaging.

5. What are the causes of spoilage of canned foods?

Spoilage of canned products may be due to two reasons:

1. Physical and chemical changes, and
2. Microorganisms.

(A) Spoilage due to physical and chemical changes

(1) Swell : When the ends of an apparently normal and perfect can with good vacuum become bulged it is termed as 'Swell or 'Blower'. The bulge is due to the positive internal, pressure of gases formed by microbial or chemical action.

i) Hydrogen swell : This type of bulging is due to the hydrogen gas produced by the action of food acids on the metal of the can. The bulging ranges from 'Flipping—to the 'Hard Swell'. The food generally remains free of harmful microorganisms and is fit for consumption.

ii) Flipper: The can appears normal, but when struck against a tabletop one or both ends become convex and springs or flips out, but can be pushed back to normal condition by a little pressure. Such a can is termed as "flipper" and may be an initial stage of swell or hydrogen swell. It may also be caused by overfilling, under-exhausting or gas pres¬sure due to spoilage.

iii) Springer: A mild swell at one or both ends of a can is called a 'springer' Which may be an initial stage of hydrogen swell or be due to insufficient exhausting or overfilling of the can. The bulged ends (or at least one end)

can be pressed back to the original position, but will again become convex after some time.

iv) Soft swell: At a more advanced stage, swell develops at both ends of the can which can be pressed and returned to normal position, but springs back when the pressure is removed. A swell of this type is termed as "soft swell" and is more or less similar to that of flipper.

v) Hard swell: This is the final stage of swell. The bulged ends cannot be pressed back to normal position and the cans ultimately burst.

The following precautions are necessary to prevent the formation of hydro-swells:

a) Good quality tin plate should be used for making the cans. The quality is related to the porosity of the tin coating. The greater the porosity, the greater is the possibility of corrosion of the can. The porosity can, however, be decreased by increasing the thickness of the coating and making it more uniform. Plain cans are less susceptible to hydrogen swell formation than lacquered cans.

b) About 0.5 per cent citric acid should be added to the syrup used for canning fruits of low acidity such as cherry, mango, papaya, etc. Citric acid checks the formation of hydrogen swell to a great extent.

c) Before placing the lid a head space of 0.6 to 0.9 cm should be left in the can which is to be exhausted.

d) The lid should be placed firmly or clinched before exhausting to ensure a high vacuum in the can.

e) Cans should be exhausted for a fairly long time, but without affecting the quantity of the product unduly. The larger the quantity of oxygen remaining in the can, the greater would be the corrosion because oxygen combines with the nascent hy-drogen formed by the action of acid cn the tin container. In the absence of air, the rate of corrosion is low. Oxygen can be excluded from the can by filling it properly and exhausting it thoroughly.

f) The sealing temperature should not be below 74°C.

g) At high storage temperature hydrogen formation will be more.

resulting finally in swell, hence canned products should be stored under cool and dry conditions.

2. Overfilling: Spoilage due to overfilling is common. During retorting, over-filled cans become strained due to expansion of the contents, and in the absence of vacuum in them swelling takes place. If the cans are properly heat exhausted, the excess material overflows from it due to expansion and thus spoilage because of overfilling is avoided.

3. Faulty retort operation: When the steam pressure is reduced rapidly at the end of processing, high pressure develops inside the cans resulting in their distortion and the cans when cooled look like "swells". Cans of very thin tin plate should not be used as they cannot withstand the pressure which develops in the cans while processing.

4. Under-exhausting : Cans are exhausted to remove most of the air. This helps in the proper filling of fruits and vegetables and also creates a good vacuum, which is necessary to accommodate any pressure that might develop inside the can as a result of production of hydrogen due to corrosion.Improperly exhausted cans may suffer severe strain during heat processing due to the large internal pressure of the gas present in it. Under-exhausted cans show strain ranging from slight flipping to distortion,

depending upon the amount of gas evolved from the product and the size of the head space.

5. Panelling : It is generally seen in large sized cans that the body is pushed inward due to the high vacuum inside. This also occurs when the tin plate is thin or the cans are pressure cooled at very high pressure. In very severe cases, seam leakage may occur but normally this is not regarded as spoilage.

6. Rust : Cans having external rust must be thoroughly examined after removing the rust and, if the walls show a pitted appearance, should be rejected as spoiled. Cans slightly affected by rust if not used immediately should be rejected. Rust is mostly seen under the label and subsequently affects the label as well. Rust formation can be checked if the cans are externally lacquered.

7. Foreign flavours : During preparation, filling, storage or even transportation, conditions may become unhygienic and the products may develop foreign or "off-flavours". If unsuitable metallic containers are used, a "metallic flavour" develops. Flavour is an important characteristic for maintaining which packages must be examined at regular intervals.

8. Damage : Rough handling of cans due to carelessness or ignorance may damage them. If any cans show signs of leakage or severe distortion they must be rejected.

9. Undesirable texture : Texture is another important characteristic, like flavour and colour, which is detected easily by a consumer. In order to maintain the standard of a product its texture should be tested periodically. Although there are no precise parameters for measuring texture, an instrument like "Tenderometer", which measures the resistance to shearing and relative tenderness, can be used for peas and beans:

Calcium salts present in the water used for canning have a "toughening effect" on peas and beans, but such hardening is considered desirable for potatoes and tomatoes.

Care should be taken that the processing of soft fruits does not result in their becoming-pulp.

10. Corrosion of cans : Cans become corroded or perforated due to the acidity of the contents, specially highly acid fruits. In recent years, attempts have been made to reduce the spoilage by using improved lacquers for internal coating of cans.

11. Leakage : A leaking can is known as a "Leaker". This may be due to: (i) defective seaming, (ii) nail holes caused by faulty nailing of cases while packing, (iii) excessive internal pressure due to microbial spoilage sufficient to burst the can, (iv) internal or external corrosion, and (v) mechanical dam¬age during handling.

12. Breathing : There may be a very tiny leak in the can through which air can pass in and destroy the vacuum. In such cases the food is damaged due to rusting of the can caused by oxygen in the air but still remains fit for con-sumption.

13. Bursting : This may be caused by the excess pressure of gases produced by decomposition of the food by microorganisms, or by hydrogen gas formed by the chemical action of food acids on the tin plate. In such cases the canned product cannot be used.

6. Write any five advantages of plastic for packaging.

1. Plastic packages are pilfer-proof, temper-proof, break-resistant, corrosion- resistant and leak proof.
2. Plastic can be processed into any desired shape or form, such as films, sheets, bottles, tubes, pouches, crates, etc.
3. Plastic packages do not pose any major disposal problem or environmental hazard, since almost all plastics can be recycled for reuse.
4. Plastics are light and less bulky than other packaging materials, which results in saving in cost of storage and transportation.
5. Some new plastics have excellent barrier properties to moisture, odour, oxygen and other gases so that the desired shelf-life of various products can be maintained.

13.6 LET US SUM UP

In this unit, we looked at the preserve, protect and maintain the contents in a fit and palatable condition.
Then we studied about some of the important types of packaging.
We also discussed about functions of food packaging and types of containers.
The last part of the unit focused on canning and Bottling of fruits and vegetables and also discussed about advantages and limitations of plastics for packaging were highlighted in this section.

13.7 UNIT- END- EXERCISES

1. Explain the functions of packaging foods
2. Give the classification of package of foods.
3. Bring out the recent advantages in packaging material. How are they superior to the traditional ones.
4. List the packaging material suitable for different foods.
5. Explain the laws related to packaging.
6. What is the importance of Nutrition Labelling to the consumer and manufacturer?
7. Give the laws related to labeling of foods.
8. Give guidelines for nutrition labeling according to codex alimentarus.

13.8 ANSWER TO CHECK YOUR PROGRESS

1. **The major objectives of packaging**
   - ❖ To preserve, protect, and maintain the contents in a fit and palatable condition.
   - ❖ To withstand the chosen selling and distribution method
   - ❖ To furnish a design and appearance which should be attractive to the customer, easy to open, dispense, store and finally dispose of.
   - ❖ To provide an economical container.
   - ❖ To make it easier and safer to transport.

- ❖ To prevent or minimize losses of the product.
- ❖ To provide a convenient means for dispensing the product

2. **Basic Packaging materials for Flexible Packaging**
   - ❖ Paper
   - ❖ Plastics
   - ❖ Cellophanes
   - ❖ Polyethylene
   - ❖ Polypropylene(PP)
   - ❖ Pliofilm
   - ❖ Polyfluorocarbons
   - ❖ Polyamides
   - ❖ Water – Soluble and Edible Films
   - ❖ Other Films
3. Retort Pouch Materials
   - ❖ Glass
   - ❖ Tin Foil
   - ❖ Aluminium Foil
   - ❖ Metal Cans
   - ❖ Lids
4. Types of packaging
   - ❖ The retail outlet, either a single-serve,
   - ❖ That comprising either institutional packaging for mass feeding centers.

13.9 SUGGESTED READINGS

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UNIT XIV – FOOD LAWS AND STANDARDS – BUREAU OF INDIAN STANDARDS – CONSUMER PROTECTION ACT, 1986 – INTERNATIONAL STANDARDS

14.1. Introduction
14.2. Objectives
14.3. Food Laws and standards
14.4. Bureau of Indian standards
14.5. Consumer protection Act, 1986
14.6. International standards
14.7. Let Us Sum Up
14.8. Unit- End- Exercises
14.9. Answer to check your Progress
14.10. Suggested Readings

14.1. INTRODUCTION

The Government of India is fully aware to the possibilities of food being adulterated. It has therefore, empowered several agencies and promulgated a number of acts and orders to contract the menace. Agencies and institutions have also been created to lay down standards for the quality of foods. The manner in which the food is processed and packaged is also covered by a number of regulations. Following measures have been taken by the government to control the quality of food.

14.2 OBJECTIVES

After going through the unit you will be able to;

- Understand protect the health and safety of consumers by reducing food-related risks.
- To help consumers make informed choices about food by making sure they have information they need and are not misled.
- To support public health by promoting healthy food choices; maintaining and enhancing the nutritional qualities of food and responding to specific public health concerns.
- To provides safe food controls to protect health and safety.
- To reduces the burden of laws and compliance on the food sector.
- To provides cost effective compliance and enforcement arrangements for industry, government and consumers.
- To recognize that responsibility for food safety includes all levels of government.

14.3 FOOD LAWS AND STANDARDS

One of the early acts to be promulgated in this connection was the Prevention of Food Adulteration Act of 1954, which has been in force since June 1,1955. The objective of this act was to ensure that food articles

sold to the customers are pure and wholesome. It also intended to prevent fraud or deception and encourages fair trade practices. The act was amended in 1964 and again in 1976 in the light of experience gained, to plug loopholes of escape in the Act and to insure stringent punishment for those indulging in this nefarious practice.

The Act prohibits the manufacture, sale and distribution of not only adulterated foods but also foods contaminated with toxicants and misbranded foods. A Central Food Laboratory located at Calcutta and the Central Food Technological Research Institute, Mysore has also been recognized for testing of adulterated foods. "A central committee for food standards" has been constituted under the Act and has been charged with the function of advising the Central Government on matters relating to the Food standards.

According to the Act, an article of food shall be deemed to be adulterated.

- ❖ If the article sold by a vendor is not of the nature, substance or quality demanded by the purchaser and as it is represented to be.
- ❖ If it contains any other substance or processed as to affect injuriously the nature.
- ❖ If any inferior or cheaper substance has been substituted wholly or in part for the article.
- ❖ If the article had been prepared, packed or kept under unsanitary conditions whereby it has become contaminated or injurious to health;
- ❖ If the article consists of any filthy, putrid, disgusting, rotten, decomposed or diseased animal or vegetable substance or is insect-infested or otherwise unit for human consumption.
- ❖ If the article is obtained from a diseased animal;
- ❖ If the article contains any poisonous or other ingredient which renders its contents injurious to health;

14.3.1. Administrative hierarchy

- ❖ The Food Health Authority is appointed at state level who is the Director of Public Health and Preventive Medicine. He is responsible for the good quality and standards of foods available to the consumers.
- ❖ Under FHA is the Local Health Authority (LHA). There is a Local Health Authority appointed in each city in every state.
- ❖ The food Inspector is appointed by the Central or State Government by notification in official gazette. The Food Inspector undergoes a three months training in food inspection and sampling.

14.3.2. Powers of food inspectors

1. To take sample of any food article from
   - ❖ Any person selling such article.
   - ❖ Any person who is in the course of delivering or preparing to deliver such article to a purchaser or consignee.

- A consignee after delivering of any such article to him.

2. To send such sample for analysis to the Public Analyst (PA) of local area.

14.3.3. Fruit Products Order

The Government of India promulgated a Fruit Products order in 1946. In 1955, the order was revised. The Fruit Products Order (FPO) lays down statutory minimum standards in respect of the quality of various fruits and vegetable products and processing facilities.The FPO and PFA, are enforced by the Department of Health.

14.3.4. Meat products order

It rovides means to:

- Detect and destroy meat of diseased animals.
- Ensure that the preparation and handling of meat and meat products be conducted in a clean and sanitary manner.
- Prevent the use of harmful substances in meat roods.
- See that every cut of meat is inspected before sale to ensure its wholesomeness.

The order also lays down rules and conditions for procedure to be adopted for the selection of disease-free animals, slaughterhouse practices.

14.3.5. Cold storage order

The cold storage order, 1980, promulgated under the Essential commodities Act, 1955, has the objective of ensuring hygienic and proper refrigeration conditions in a cold store, regulating the growth of cold storage industry and rendering technical guidance for a the scientific preservation of food stuffs.

i. Standards

I.S.I. Standards

Various committees, including representatives from the government, consumers and industry, formulate the Indian Standards Institution (ISI). Standards are laid for vegetable and fruit products, spices and condiments, animal products and processed foods.

The products are checked for quality by the ISI in their own network of testing laboratories at Delhi, Bombay, Calcutta, Madras, Chandigarh and Patna or in a number of public and private laboratories recognized by them.

ii. The AGMARK Standard

The AGMARK standard was set up by the Directorate of Marketing and Inspection of the Government of India by introducing an Agricultural produce Act in 1937. The word 'AGMARK' seal ensures quality and purity. A sample AGMARK seal is as below

- ✓ AGMARK BESAN
- ✓ SL.NO. B-162002
- ✓ GRADE-STANDARD
- ✓ PLACE OF PACKAGING…….
- ✓ DATE OF PACKAGING……
- ✓ NET WEIGHT……..

The quality of a product is determined with reference to the size, variety, weight, colour, moisture, fat content and other factors are taken into account. The grades incorporated are grades 1,2,3 and 4 or special, good, fair and ordinary.

iii. Export inspection council

The council has been constituted to check the quality of a number of food materials meant for export. The council has powers to reject any food, which does not measure up to the standards prescribed for the food. Canned food such as mango juice, pineapple juice, frozen food such as shrimp, pomfrets are subject to scrutiny by this body before export.

14.3.6. The Food Safety and Standards Act, Rules and Regulations

- ❖ The Food Safety and Standards Act of 2006 (No. 34 of 2006) enacted on August 24, 2006 which mandated setting up of a independent autonomous body Food Safety & Standards Authority of India.
- ❖ Food Safety & Standards Rules - cover administrative structure and functioning of FSSAI and various bodies under it.
- ❖ Food Safety and Standards Regulations - cover the various regulatory & compliance aspects of the food industry like licensing, labelling, use of additives, food standards etc.

14.3.7. The various regulations

- ❖ Licensing and Registration
- ❖ Packaging & Labelling
- ❖ Food Standards
- ❖ Food Additives
- ❖ Contaminants & Toxins
- ❖ Prohibitions and Restrictions
- ❖ Laboratory sampling and Analysis

14.3.8. The Repeals

SECOND SCHEDULE (Section 97) – Following Acts /Orders get repealed

1. The Prevention of Food Adulteration Act, 1954 (37 of 1954).
2. The Fruit Products Order, 1955.
3. The Meat Food Products Order, 1973.
4. The Vegetable Oil Products (Control) Order, 1947.
5. The Edible Oils Packaging (Regulation) Order, 1998.
6. The Solvent Extracted Oil, De oiled Meal, and Edible Flour (Control) Order, 1967.

7. The Milk and Milk Products Order, 1992.
8. Any other order issued under the Essential Commodities Act, 1955 (10 of 1955) relating to food.

All provisions of these will get covered in the new regulations

14.3.9. Few important definitions

Food - "any substance whether processed, partially processed or unprocessed, which is intended for human consumption and includes primary food (except the produce in the hand of a farmer or a fisherman), genetically modified foods or foods having genetic ingredients, infant foods, packaged drinking water, alcoholic drink and also includes water used in food during manufacture or preparation. All types of imported foods also come under the purview of this Act.

The provisions of this Act shall not apply to any farmer or fisherman or farming operations or crops or livestock or aquaculture, and supplies used or produced in farming or products of crops produced by a farmer at farm level or a fisherman in his operations.

- The administrative structure

The Food Safety & Standards Authority - the apex body with 1 chairperson and 22 members in charge of complete administration of the Food Safety Act with the objective of regulating and monitoring the manufacture, processing, distribution, sale and import of food

- The authority to be advised by
  - ✓ Central Advisory Committee – mainly in administrative & Enforcement matters
  - ✓ Scientific Committee & Scientific Panels on technical matters.
- Details of Authority's role – Section 16

14.3.10. Licensing and registration

Salient feature

- Unified Licensing procedures - Single Window
- Common application forms and procedures.
- Distinction between 'registration' and 'licensing'. Cut off limits for registration and licensing.
- Two tier system of licensing – Central & State
- Introduction of exhaustive Safety, Sanitary and Hygienic conditions mandatory for registration/licensing.
- Intention to reduce inspections, more audit of system 60 days time limit for processing of license.
- Thrust on Preventive Actions

14.3.11. Registration Procedure - for petty manufacturers

- ❖ Registration shall not be refused without giving the applicant an opportunity of being heard and for reasons to be recorded in writing.
- ❖ On grant of registration, a registration certificate and a photo identity card shall be issued which shall be displayed at a prominent place at all times within the premises or vehicle or cart or any other place where the person carries on the Petty Food Business.
- ❖ The Registering Authority or any officer or agency specifically authorized for this purpose shall carry out food safety inspection of the registered establishments at least once in a year.

14.3.12. Product compliance related- labeling, standards & additives

- ❖ The requirements notified in a structured format - different regulations for
    - ✓ Packaging & Labeling
    - ✓ Food Standards and Additives
    - ✓ Contaminants & Toxins
    - ✓ Prohibitions and restrictions
    - ✓ Laboratory sampling and Analysis
- ❖ Act has mentioned few areas where new work would have to start
    - ✓ Food Recall - Authority shall make regulation to lay down conditions and guidelines on food recall
    - ✓ New standards for GM foods, nutraceuticals, Food supplements etc.

14.3.13. Guidelines in act for setting standards - a major change

a. Endeavour to achieve appropriate level of protection of human life and health and the protection of consumer’s interests, including fair practices in all kinds of food trade with reference to food safety standards and practices;

b. Carry out risk management which shall include taking into account the results of risk assessment and other factors relevant to the matter;

c. Where on the basis of assessment of available information, the possibility of harmful effects on health is identified but scientific uncertainty persists, provisional risk management measures necessary to ensure appropriate level of health protection may be adopted

d. The measures adopted on the basis of clause (c) shall be proportionate and no more restrictive of trade than is required to achieve appropriate level of health protection,

e. regard being given to

- ❖ Technical and economic feasibility and other factors regarded as reasonable and proper in the matter under consideration;
- ❖ Taking into account prevalent practices and conditions in the country including agricultural practices and handling, storage and

transport conditions; and International standards and practices, where international standards or practices exist.

14.3.14. Food labeling, standards & Additives

- Same as PFA – standards - About - 300 odd standards
- All others proprietary - require Approval from Authority – application to be filed in prescribed format
- Novel Foods
- Labeling on products
  - ✓ Standardized products
  - ✓ Proprietary products

14.3.15. Food standards & Additives

- Specific Regulation on Standards
- Proprietary products - need to follow the general requirements
- Specific regulation on Additives
- Product specific allowance
- Proprietary –
- Contaminants and Toxins
- Prohibitions and restrictions
- Import regulations – draft

14.3.16. Special requirement for imported food

- All Imported foods to comply with all mentioned Regulations
- Balance shelf life
- Procedures for Import clearance – a draft regulation issued
  - ✓ Authorized officer having similar powers as FSOs
  - ✓ License from Central Licensing Authority
  - ✓ Provision of Risk Based Framework
  - ✓ Alerts
  - ✓ Accelerated clearance – Agreement with exporting countries
  - ✓ Pre Approval Notification
  - ✓ Accredited food importer programme
  - ✓ Special consideration for specific type of Import

14.3.17. Additional labeling requirement under legal metrology (Packaged Commodities) Rules

- MRP
- Specific conditions for declaring Net weight - Metric unit
- Consumer care no/email
- Packaging in specific sizes for commonly used
- products

Check your progress - 1
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.
1. What is food laws and regulations?

2. What are the Types of Food Packaging?

1. What is food laws and regulations?

In order to promote a safe, honesty food supply and to prohibit the sale of foods that are unsafe, contaminated, and adulterated every nation needs an effective food legislation and food control service. Food act sets broad principle and Food Regulation contains detailed provisions.

2. What is Food Safety and Standards Act 2006?

Food Safety and Standards Act, 2006. ... FSSAI regulates the food sector by laying down guidelines and standards to be followed by food businesses. It also specifies procedures for accreditation of laboratories and provides advice to central and state government in matters relating to food safety.

14.4. BUREAU OF INDIAN STANDARDS

14.4.1. Food Standards

Effective food standards and control systems are required to integrate quality into every aspect of food production and service, to ensure the supply of hygienic, wholesome food as well as to facilitate trade within and between nations. There are four levels of standards which are well coordinated.

a. Company Standards:

These are prepared by a Company for its own use. Normally, they are copies of National Standards.

b. National Standards:

These are issued by the national standards body.

c. Regional Standards:

Regional groups with similar geographical, climate, etc. have legislation standardisation bodies.

d. International Standards:

The International Organisation for Standardisation (ISO) and Codex Alimentarius Commission (CAC) publish international standards.

14.4.2. Food Standards Regulations in India

The Prevention of Food Adulteration Act 1954 (PFA, 1954) was enacted by the Government of India to prevent adulteration of food. The Act has been amended as per need, numerous times (over 200 amendments). All food products manufactured in India, or imported and sold in India have to meet the requirements prescribed under this Act. In

addition to PFA, there are other Orders or Acts that help to ensure quality of specific foods such as :

1. Fruit and Vegetable Product Order: Specifications for fruit and vegetable products are laid down.
2. Meat Food Products Order: Processing of meat products is licensed under this order.
3. Vegetable Oil Products Order: Specifications for vanaspati, margarine and shortenings are laid down.

Voluntary product certification: There are voluntary grading and marking schemes such as ISI mark of BIS and Agmark. The Bureau of Indian Standards (BIS) deals with standardisation of various consumer goods including food products and runs a voluntary certification scheme known as 'ISI' mark for processed foods. Agmark is a voluntary scheme of certification of agricultural products (raw and processed) for safeguarding the health of consumers.

Since the government had several regulations and laws, food industry found it cumbersome. A need was therefore felt to integrate all such laws for regulating the quality of food. With this in view, Indian Government has passed Food Safety and Standards Act (FSSA), 2006, to bring the different pieces of legislation pertaining to food safety under one umbrella.

FSSA, 2006: The objects of the Act are to consolidate the laws relating to food. The Food Safety and Standards Authority of India was established for laying down science-based standards for food and to regulate their manufacture, storage, distribution, sale and import, to ensure availability of safe and wholesome food for human consumption. The Act has provisions for maintenance of hygienic conditions in and around manufacturing premises, assessment and management of risk factors to human health in a scientific manner, which were not specified in the PFA. The FSSA reflects the international shift in food laws, from compositional standards or vertical standards to safety or horizontal standards.

14.4.3. Food Safety Management Systems

Over the years, issues related to food safety and quality have gone beyond just the avoidance of food-borne pathogens, chemical toxicants and other hazards. A food hazard can enter/come into the food at any stage of the food chain, therefore, adequate control through out the food chain is essential. Food safety and quality can be ensured through:

- Good Manufacturing Practices (GMP)
- Good Handling Practices (GHP)
- Hazard Analysis Critical Control Points (HACCP)

i) Good Manufacturing Practices (GMP):

are a part of quality assurance to ensure that manufacturers/processors take proactive steps to ensure that their products are safe. It enables to minimise or eliminate contamination and false labelling, thereby protecting the consumer from being misled and helping in purchasing products that are not harmful. GMP is a good business tool

that helps to refine compliance and performance by the manufacturers/producers.

ii) **Good Handling Practices:**

indicate a comprehensive approach from the farm to the store or consumer, in order to identify potential sources of risk and indicates what steps and procedures are taken to minimise the risk of contamination. It ensures that all persons who handle food have good hygiene practices.

iii) Hazard Analysis Critical Control Point (HACCP):

HACCP is a means of providing assurance about safety of food. HACCP is an approach to food manufacture and storage in which raw materials and each individual step in a specific process are considered in detail and evaluated for its potential to contribute to the development of pathogenic micro organisms or other food hazards. It involves identification of hazards, assessment of chances of occurrence of hazards during each step /stage in the food chain – raw material procurement, manufacturing, distribution, usage of food products and defining measures for hazard(s) control.

14.4.4. Why implement HACCP?

- It is a preventive approach to ensure food safety.
- End product inspection and testing, although important, is time consuming, expensive and detects the problems only after they occur. In contrast, HACCP enables us to detect hazards at any stage of processing or manufacture in order to ensure a good quality end product, by taking appropriate action at the stage where the problem occurs.
- It enables producers, processors, distributors and exporters to utilise resources efficiently and in a cost effective manner for assuring food safety.
- FSSA, 2006 places primary responsibility for safe food with producers and suppliers through HACCP, GMP, GHP. This is important for consumer protection and international food trade.
- It assures consistently good quality products.

14.4.5. Scope

India is experiencing growth in the area of food processing. The food industry in India accounts for about 26 per cent of the gross domestic product (GDP) and will be one of the major growth areas in the years ahead. This has given impetus to international trade but has also increased the responsibility to achieve appropriate level of safety in terms of sanitary and phyto-sanitary protection. Further, the Indian Food Safety and Standards Act of 2006, reflects a major shift in food laws and seeks to provide greater consumer protection by ensuring safety and wholesomeness of food at all stages of the food chain. This changing scenario has widened the scope and increased career options/opportunities in this area. Professionals who take up careers in this area need to have

adequate knowledge and expertise in Food Chemistry, Food Processing and Preservation, Food Analysis and Quality Control. It is also desirable to be well versed in Food Microbiology, Food Laws and Sensory Evaluation. Professionals may be employed with regulatory and public health agencies as food legislators, food safety officers (inspectors), food analysts/public analysts. Professionals can also work in voluntary agencies such as Agmark, BIS, as well as in the Quality Control Laboratories. One can work as food auditor after undergoing required training. Further, large food industries, flight kitchens, etc. have in-house quality control units which require trained professionals.

Self-employment and Entrepreneurship: One can initiate entrepreneurship activities through analytical food laboratory, food safety consultancy and Food Safety and Sanitation Education. Placement options are emerging at different levels in both regulatory and health agencies. Integrated approaches in Home Science curriculum, especially in the discipline of Food Science and Nutrition, impart the knowledge to improve safety and quality. The courses enable to develop skills necessary to understand and manage food safety hazards.

14.4.6. National Regulations: PFA, AGMARK, BIS and FSSAI

In India, we have mostly two types of standards, which govern the sale of foods including milk and milk products. These are: Legal standards and Quality standards. Moreover, we had many bodies enforcing standards. This led to lot of confusion for both manufacturers as well as enforcers. In the recent past the concept of globalization or flat word has emerged very strongly, where all the boundaries have been eliminated. However, some barriers to trade with respect to more stringent norms and others have been raised. In this context Indian Standards needed to be harmonized within themselves as well as with the international standards. To eliminate the problems and confusions in the trade of food items including milk, a thought of uniform standards was evolved, which has been culminated in the form of Food Safety and Standards Authority of India.

a. Legal Standards

Legal standard means the specifications or the requirements which pertain to the law of the Govt. and are set up by the Govt. to meet certain minimum requirements in terms of chemical quality (i.e. composition), bacteriological quality (i.e. hygienic quality), and labeling and packaging requirements.

In our country, legal standards are given under PFA Rules, 1955 (which are amended from time to time). Legal standards or PFA standards prescribe the minimum requirements for all types and categories of food. These standards are consistent with the minimum quality that is attainable under Indian conditions by the majority of the farmers, producers, processors, sale agencies etc. Further, any food that does not confirm to the minimum standards laid down by the legal rulers (PFA rules) is said to be adulterated, irrespective whether anything has been added to or removed from the original food.

Parameters Generally Taken into Consideration while Fixing Legal Standards

b. Purity

There should be a mention of purity in clear terms i.e. whether anything can be added or removed from the original food should be clearly specified in the rules.

c. Composition

Certain compositional criteria should also be clearly specified in the rules, as to what should be the minimum level of components in a given type of product. For example, fat and solids-not-fat content in milk, fat in whole milk powder, cream, paneer etc. Similarly, moisture in ghee, butter, skim milk powder etc. Likewise, all the compositional requirements should be specified for all the dairy products.

d. Additives

If any additives are required to be added to any food to improve its quality, stability, flavour etc, these should be clearly specified in the rules with respect to their levels etc. For example, certain additives are permitted like nisin (preservative) in cheese, BHA (antioxidant) in ghee, butter, whole milk powder etc.

e. Efficiency of processing

It should be clearly specified in the rules as to which types of tests have to be performed to check the efficiency of heat processing treatments given to milk and milk products. For example, phosphatase test should be negative for pasteurized milk; turbidity test should be negative for sterilized milk.

f. Bacteriological quality (Hygienic quality)

Permissible limits for coliform count, total count, yeast and mould count etc should be clearly specified in the rules

g. Packaging and labeling requirements

There should be mention in the rules as to what type of packaging material is to be used for what type of food and what should be indicated on the labels like quantity, price, manufacturing date, expiry date etc.

h. Quality Standards

- ❖ Quality standards means those specifications which are laid down by the Govt or some expert body constituted by the Govt. for the purpose of producing high quality products.
- ❖ While legal standards are compulsory, the quality standards are not compulsory. They are on voluntary basis.
- ❖ In our country, we have two types of quality standards
    - ✓ BIS/ ISI standards

- ✓ Agmark standards

- ❖ Both of these are above the PFA minimum standards. Both of these are useful for producing export quality products.
- ❖ BIS/ISI standards deal with many types of processed food products, apart from non-food products. Similarly, Agmark standards deal with many types of foods, mainly with the raw agricultural produce. For example: cereals, oils, oil seeds, spices, eggs, legumes (pulses), ghee, butter etc.
- ❖ Among the dairy products, for the purpose of quality standards, ghee and creamery butter (Table butter or salted butter) are covered under Agmark. Rest of the dairy products is covered under BIS/ISI.
- ❖ As stated earlier, Agmark and BIS are voluntary and not compulsory; but in 1987, BIS has made it compulsory or mandatory for certain items to have ISI mark. For example, for food colors and additives, vanaspati, containers for packing, milk powder and condensed milk. Therefore, for these two milk products (milk powder and condensed milk), it is now compulsory to have ISI mark.

i. Why Do We Need Legal and Quality Standards?

The main purpose of these standards is to protect the interest of the consumer, although in a way the interest of the manufacturer also gets protected, because if it is a certified product with some quality mark (like ISI, Agmark), it will sell more as compared to the uncertified product.

Moreover, customer also wants to be sure about quality. He does not mind to pay a little more for an assumed quality product i.e. certified product.

Furthermore, someone has to protect the interest of the consumer. They should not be left at the mercy of the manufacturers, because he is ignorant about the quality. Consumer should get a product of pure quality (i.e. unadulterated) free from pathogenic organisms and also free from harmful substances like pesticides, antibiotics, heavy metals (toxic metals like Arsenics, lead, mercury etc), and toxins etc.

So, it is the duty of the Govt. to fix legal standards to protect the interest of the consumer and also to fix quality standards so as to improve the quality of the product to a higher degree above the minimum legal (PFA) standards.

14.4.7. PFA Act and Rules

PFA stands for Prevention of Food Adulteration. The PFA Act was passed in 1954 and PFA Rules were framed in 1955 to protect the consumers against the supply of inferior quality or adulterated food. In recent years the Govt. of India has enacted another Act known as “The Food Safety and Standards Act, 2006”, abbreviated as FSS Act 2006. The regulations under this act have come into force from Aug, 2011.

i. The main objectives of PFA Act are:

- ❖ To protect the public from harmful and poisonous foods.
- ❖ To prevent the sale of substandard food containing harmful substances, and

- To protect the society against unscrupulous and anti-social dealers by eliminating fraudulent practices.

PFA standards are formulated and revised by an expert body called Central Committee for Food standards (CCFS) under the Directorate General of health Services, Ministry of Health and Family Welfare. It is the CCFS which advices the Central Govt. and the State Govt. on matters arising out of the administration of PFA Act. It is a very heavy committee .People from all the States and the Union Territories (UTs) and all the major Ministries and departments are representative of this committee.

Procedure for Collection and Analysis of PFA Samples

PFA samples are collected by Food Inspectors. After collecting the samples, he divides the sample then and there into 3 parts. One part is sent for analysis to Public Analyst (under the control of local health authority, usually the chief medical officer (CMO). Two parts are given to local health authority (LHA) for custody.

The public analyst has to send the report of analysis within 40 days of receipt of sample. In case of adverse report of public analyst, the 2nd part of sample is produced in the court within 7 days and the copy of report is given to party i.e. accused by the local health authority (CMO). Within a period of 10days of the report, LHA or party concerned or both of them may make an application to the court for getting the 2nd part of the sample analyzed at Central Food Laboratory (CFL).

On receipt of such report, the court sends the 2nd part of sample for analysis to Director, CFL, who has to send a certificate on the result of analysis within one month from the receipt of 2nd part of sample.

The 3rd part of the sample is kept to meet such exigencies like damage /destruction / breakage on the way when first part of sample is sent to Public Analyst for analysis.

The report of public analyst on 1st part of the sample stands superseded by the certificate issued by the Director, CFL on analysis of the 2nd part of the sample.

There are several Public Health Laboratories (also called Public Food Laboratories) in the country where first part of the sample is analysed. Almost each district has such a lab under the control of Chief Medical Officer (called Local Health Authority).

But there are only four CFL (central food laboratories) in the country. These are located at Kolkata, Mysore, Pune and Ghaziabad. All these 4 CFLs take care of the requirements of whole country, Zone wise. In fact the whole country is divided into 4 Zones and each zone is then connected to one of these CFL. Samples of a particular area/zone are sent to the concerned CFL.

ii. Preservative Permitted To Be Added To Samples

When a food inspector takes the sample of any food for analysis, he has to add a preservative, as may be prescribed from time to time, so as to keep the sample in a condition suitable for analysis. The preservative used in the case of samples of any milk (including toned, separated and skimmed milk, standardized milk chhanna, skimmed milk chhanna, cream, ice-candy, dahi, khoa or khoa based or paneer based sweets, such as kalakand and burfi, chutney and prepared foods, gur,coffee and tea in liquid and semi liquid form, shall be the liquid commonly known as "formalin", a liquid containing about 40 percent of formaldehyde in aqueous solution in the proportion of 0.1 ml (two drops) for 25ml or 25grams (i.e.@ 0.4%). Provided that in case of ice-cream and mixed ice-cream, the preservative used shall be in the proportion of 0.6 ml for 100 ml or 100 gm (i.e.@ 0.6%).

14.4.8. Agriculture Produce (Grading and Marking) Act (AGMARK)

Agmark stands for "Agricultural Marking". In order to have a systematic marketing of Agricultural Produce on the basis of well defined quality, Indian Legislature in 1937 passed an act known as "Agriculture Produce (Grading and Marking) Act, 1937. This act is not mandatory. It is permissive in nature. It is one's choice to go for Agmark grading, if one can meet their specifications. Rules under this Act are called "General Grading and Marking Rules, 1937". Rules have been revised in 1988 and are called General Grading & Marking Rules, 1988. Grading of Agricultural items under these rules is called AGMARK GRADING or Agmark certification.

Agmark is the exclusive property of Govt. of India. It is not a private trade mark. Directorate of Marketing & Inspection (DMI) is the authority on the Agmark whose head quarter is now at Faridabad and branched head quarter is at Nagpur. It is the DMI which enforces the Agricultural Produce Act, 1937.

Under the Agricultural Produce Act, 1937-grade standards are given for agricultural and allied commodities like cereals, oil seeds, oils, creamery butter, ghee, legumes, eggs etc. Agricultural commodities are categorized into various grades such as, special, good, fair, ordinary etc depending upon the degree of quality (type of composition) in each case. These grades are known as "Agmark Standards" and this way of categorizing or grading the agricultural products in terms of their chemical composition or quality is called "Agmark Grading".

1. **Objectives of Agmark Scheme**

- To assure the consumers a product of pre-tested quality & purity.
- To enable the producer of good quality products to have better returns.
- To have a sale of the product in the market with a uniform composition and well defined quality.
- To eliminate the malpractice of adulteration in the movement of the product from producer to consumer.

As told earlier, among the dairy products, only ghee and creamery butter (Table butter or salted butter) are graded under Agmark. Deshi or cooking (unsalted or white) butter is not graded under Agmark.

2. **How The Certificate of The Authority To Use Agmark Labels Is Obtained**?

Interested parties who wish to get authority to use Agmark Labels have to apply to the Agricultural Marketing Advisor (AMA) to Govt. of India at Directorate of Marketing & Inspection (DMI) whose H.Q is at Faridabad (Branched H.Q. at Nagpur). Application by the party concerned should be submitted through the state marketing officer.

Interested parties should meet the following pre-requisites so as to get the authority to use Agmark labels.

- They should have well equipped, hygienic site and hygienic equipments.
- They should have well equipped lab.
- They should have qualified staff like butter makers having 5 years experience or possessing a certificate of proficiency from a recognized agricultural or dairy institute. Similarly, a chemist with dairying degree in dairying.
- Packers of pasteurized table butter should have pasteurizing plant and cold storage facilities.
- Cream separating station, if separate, that also should be hygienic.
- They should have quality control checks on cream and raw materials so as to ensure that no adulteration with animal or vegetable fat takes place.
- Packing containers should be clean and rust free.
- No vegetable fat, animal body fat and no artificial flavoring or coloring matter should be seen near the factory and cream separating station.
- Ghee clarification temperature should never go above 110°C.
- They should also send one sample of butter/ghee to Regional Agmark Lab or any other specified lab at regular intervals as advised by AMA.

All instructions from AMA will have to be followed strictly. For example, method of sampling, method of sealing and marking of tins or cartons, maintenance of records, labeling procedure as prescribed by AMA. Upto date record of labels to be kept, labels to indicate clearly the designation (pasteurized butter, special & general grade of ghee etc) and serial number of label. Container should indicate the name of packer, batch no. (Melt no), date of packing, net weight and Certificate of Authorization (CA) number.

Now if parties concerned can afford, then write to AMA at Faridabad/Nagpur through state marketing officer. Then, AMA or his authorized persons will inspect the premises, the facilities and technical staff etc. After satisfaction, AMA issues the necessary certificate of

authority to use Agmark Labels. Certificate of Authorization is renewed periodically on the basis of the past performance of the authorized packer.

3. **How The Agmark Scheme Operates In Case Of Butter & Ghee?**

- Once the authority to use Agmark Label for butter/ghee is obtained, then usually the Agmark people employ their chemist (called Agmark chemist) in the factory.
- All the operations right from the stage of manufacturing the product to the stage of packing and sealing are done under the supervision of Agmark chemist.
- Usually the butter, ghee etc are manufactured in the factory itself, but sometimes the Kacha/Raw ghee is brought to the factory by middlemen, or agents or producers, then the Agmark chemist draws sample of that Raw or Kacha ghee and analyses for BR reading, FFA, Baudouin test, RM and Polenske value etc for his satisfaction about its purity, before its further processing.
- After the manufacturing of every batch of butter or ghee, but before the packing and sealing, the product is tested for purity and quality by the Agmark chemist as per the Agmark standard of the concerned product.
- Agmark chemist draws two samples of butter, one is analysed and second is sent to Regional Agmark Laboratory as specified by AMA. Similarly in case of ghee, he draws three samples, one is analysed and second is sent to central control lab as per AMA and 3rd is given to manufacturer for future use.
- Once the Agmark chemist is satisfied with the analysis with regard to the specifications fixed under Agmark, then only labels are issued and fixed, otherwise it is denied.
- Fixing of labels is done by a special adhesive in such a manner that once fixed cannot be removed without damage.
- In case the Agmark chemist is not employed, then the authorized packer can get his product tested at the approved State Grading Laboratory (SGL).
- After the ghee and butter are packed and sealed in tins/cartons and sold in the market, the field staff of DMI collects the check samples from the market when the products are on sale in the market. These check samples are analysed at different Regional Agmark Laboratories (RAL) and the results are compared with the original. If the results agree then alright, but if the results do not agree, then appropriate action is taken, such as the product is withdrawn from the market, and the authority to use Agmark labels is cancelled etc.

14.4.9. Bureau of Indian Standards (B.I.S)

- It is a national standards body of India which is responsible for formulating National Standards for various types of articles (both edible & non-edible i.e. food & non-food articles e.g. live stock feed, cattle housing, equipments, dairy products, food additives, food hygiene), testing apparatus and methods etc.

- The old name of this organization was ISI (Indian Standards Institution), which was established in 1947. The new name i.e. BIS came into existence from 1st April, 1987 under the BIS Act 1986.

I. Structure of BIS/ Members of BIS

Membership of BIS is broad based and all important interests are represented.

Minister for food and civil supplies is the President of BIS

Members of BIS include:

- Members of Parliament,
- Ministers of state govts.,
- Nominees of central Govt. Ministries and departments,
- Farmers community,
- Consumers organizations,
- Academic institutions,
- Research institutions,
- Industry and
- Professional Associations.

II. Objectives and Functions Of BIS

- To formulate Indian standards for various articles, processes, methods of test, codes of practices etc and promote their implementation.
- To promote the Concepts of standardization and Quality control in industries.
- To coordinate the efforts of producers and users for making improvements in the materials, products, processes and methods.
- To operate ISI certification scheme.
- To establish testing laboratories of its own.
- To operate laboratory recognition scheme to meet the requirements of testing.
- To offer technical and consultancy services within and outside the country.
- To have cooperation and coordination with international standard making bodies like ISO.

III. BIS is a member of ISO and IEC

ISO- international organization for standardization.

IEC- international electro-technical commission.

IV. How to get authority to use ISI mark?

For getting an authority/or license to use ISI mark on the products, the manufactures have to apply to BIS for permission.

BIS people then send a team to inspect the factory, verify the capabilities of manufacturer to produce and also test the products on continuous basis in accordance with the relevant Indian standards.

They also check the quality of the products and other facilities and after satisfying themselves they give permission to use ISI mark.

BIS gives a well defined quality control system to the manufactures and tells them to exercise control measures at various stages like,

- ❖ Raw material,
- ❖ Diff. stages of production,
- ❖ Finished product stage.

BIS keeps a supervisory control to ensure that the ISI marks product are always in conformity with the relevant Indian standards.

BIS also has an elaborate Quality Audit System under which they draw the samples

- ❖ From the factory production line, or
- ❖ From factory store , or
- ❖ Purchase them from the open market.

And then test the samples in their own labs or recognized labs to check the conformity with the relevant Indian standards.

BIS also entertains complaints from consumers and arranges free replacements of defective ISI-marked goods.

BIS also provides training in statistical quality control to its applicants and licensees for improving their technical skill.

14.4.10. Modern Integrated Food Law (FSSA, 2006)

- In order to consolidate the laws relating to food and to establish the Food Safety and Standards Authority of India for laying down science based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import, to ensure availability of safe and wholesome food for human consumption and for matters connected therewith or incidental thereto, the Govt. of India has enacted new food laws known as "The Food Safety and Standards Act, 2006". This Act was passed on 23rd August, 2006. It extends to the whole of India.
- However, the Act came in to force only recently in 2011. This Act consolidates various acts & orders that have hitherto handled food related issues in various Ministries and Departments.

1. **Highlights of the Food Safety and Standard Act, 2006**

- ❖ Various central Acts like Prevention of Food Adulteration Act, 1954 , Fruit Products Order , 1955, Meat Food Products Order , 1973, Vegetable Oil Products (Control) Order, 1947, Edible Oils Packaging (Regulation) Order 1988, Solvent Extracted Oil, De-Oiled Meal and Edible Flour (Control) Order, 1967, Milk and Milk Products Order, 1992 etc will treated as repealed after commencement of FSS Act, 2006.
- ❖ The Act also aims to establish a single reference point for all matters relating to food safety and standards, by moving from multi- level, multi- departmental control to a single line of

command. To this effect, the Act establishes an independent statutory Authority – the Food Safety and Standards Authority of India with head office at Delhi. Food Safety and Standards Authority of India (FSSAI) and the State Food Safety Authorities shall enforce various provisions of the Act.

2. **Establishment of FSSAI**

Ministry of Health & Family Welfare, Government of India is the Administrative Ministry for the implementation of FSSAI. The Chairperson and Chief Executive Officer of Food Safety and Standards Authority of India (FSSAI) have already been appointed by Government of India. The Chairperson is in the rank of Secretary to Government of India. FSSAI has been created for laying down science based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import to ensure availability of safe and wholesome food for human consumption.

3. **Composition of Food Safety and Standards Authority of India**

The Food Authority consists of a Chairperson and the following twenty-two members out of which one-third shall be women, namely:-

(a) Seven Members, not below the rank of a Joint Secretary to the Government of India, to be appointed by the Central Government, to respectively represent the Ministries or Departments of the Central Government dealing with -

(i) Agriculture, (ii) Commerce, (iii) Consumer Affairs, (iv) Food Processing, (v) Health, (vi) Legislative Affairs, (vii) Small Scale Industries, who shall be Members ex-officio;

(b) Two representatives from food industry of which one shall be from small scale industries;

(c) Two representatives from consumer organizations.

(d) Three eminent food technologists or scientists.

(e) Five members to be appointed by rotation every three years, one each in seriatim from the Zones as specified in the First Schedule to represent the States and the Union territories;

(f) Two persons to represent farmers' organizations.

(g) One person to represent retailers' organizations.

4. Punishment for unsafe food under FSSAI

Any person who, whether by himself or by any other person on his behalf, manufactures for sale or stores or sells or distributes or imports any article of food for human consumption which is unsafe, shall be punishable,–

(i) where such failure or contravention does not result in injury, with imprisonment for a term which may extend to six months and also with fine which may extend to one lakh rupees;

(ii) where such failure or contravention results in a non-grievous injury, with imprisonment for a term which may extend to one year and also with fine which may extend to three lakh rupees;

(iii) where such failure or contravention results in a grievous injury, with imprisonment for a term which may extend to six years and also with fine which may extend to five lakh rupees;

(iv) where such failure or contravention results in death, with imprisonment for a term which shall not be less than seven years but which may extend to imprisonment for life and also with fine which shall not be less than ten lakh Rupees.

4. **Penalty for selling food not of the nature or substance or quality demanded**

Any person who sells to the purchaser's prejudice any food which is not in compliance with the provisions of this Act or the regulations made there under, or of the nature or substance or quality demanded by the purchaser, shall be liable to a penalty not exceeding five lakh rupees. Provided that the persons covered under sub-section (2) of section 31, shall for such non-compliance be liable to a penalty not exceeding twenty five thousand rupees.

5. **Penalty for sub-standard food**

Any person who whether by himself or by any other person on his behalf manufactures for sale or stores or sells or distributes or imports any article of food for human consumption which is sub-standard, shall be liable to a penalty which may extend to five lakh rupees.

7. Penalty for possessing adulterant

(1) Subject to the provisions of this chapter, if any person who whether by himself or by any other person on his behalf, imports or manufactures for sale, or stores, sells or distribute any adulterant shall be liable –

(i) where such adulterant is not injurious to health, to a penalty not exceeding two lakh rupees;

(ii) where such adulterant is injurious to health, to a penalty not exceeding ten lakh rupees.

(2) In a proceeding under sub-section (1), it shall not be a defence that the accused was holding such adulterant on behalf of any other person.

As per new norms the Milk and Milk Products Order, 1992 shall be deemed to be regulations made under this Act.

(1) On and from the date of commencement of this Act, the Milk and Milk Products Order, 1992 issued under the Essential commodities Act, 1955

(10 of 1955) shall be deemed to be the Milk and Milk Products Regulations, 1992 issued by the Food Authority under this Act.

(2) The Food Authority may, with the previous approval of the Central Government and after previous publication, by notification, amend the regulations specified in sub-section.

In FSSAI, to harmonise the codex standards, "Codex India" the National Codex Contact Point (NCCP) for India, has been constituted. This point is located at Food Safety and Standards Authority of India (Ministry of Health and Family Welfare), FDA Bhawan, Kotla Road, New Delhi - 110002, India. It coordinates and promotes Codex activities in India in association with the National Codex Committee and facilitates India's input to the work of Codex through an established consultation process.

Check your progress - 2
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.
3. What is PFA rule?
4. What is Agmark?

3. What is PFA rule?

The corrigendum refers to the Prevention of Food Adulteration (Fourth Amendment) Rules 2005 framed under the Prevention of Food Adulteration Act (PFA), 1954, regarding standards for dairy products.

4. What is Agmark?

AGMARK stands for Agriculture Mark. AGMARK sign is issued and certified by govt. of India directorate of marketing and inspection. It is used to certify the authentic standards for agricultural products.

14.5 CONSUMER PROTECTION ACT, 1986, INTERNATIONAL STANDARDS

14.5.1 The consumer protection Act, 1986 act no. 68 of 1986

A consumer is a user of goods and services, therefore, every producer is also a consumer. However, conflicting interests have categorised them, inevitably, into two different groups. The industrial revolution brought in the concept of standardisation and mass production and over the years, the type of goods and the nature of services available grew manifold. The doctrine of ‘Caveat Emptor’ or ‘let the buyer beware’ which came into existence in the middle ages had been replaced by the principle of ‘Consumer Sovereignty or ‘Consumer is the King’. But, with tremendous increase in the world population, the growing markets were unable to meet the rising demand which created a gap between the general ‘demand’ and ‘supply’ levels in the markets. This to some extent watered

down the concept of 'Consumer Sovereignty', what with consumers being forced to accept whatever was offered to them. On the other hand, the expanding markets necessitated the introduction of various intermediaries between the producer and the ultimate consumer. 'Advertising', though ostensibly directed at informing potential consumers about the availability and uses of a product began to be resorted to as a medium for exaggerating the uses of ones products or disparaging others products so as to have an edge over competitors. Unfair and deceptive practices such as selling of defective or sub-standard goods, charging exhorbitant prices, misrepresenting the efficacy or usefulness of goods, negligence as to safety standards, etc. became rampant. It, therefore, became necessary to evolve statutory measures, even in developed countries, to make producers/traders more accountable to consumers. It also became inevitable for consumers to unite on a common platform to deal with issues of common concern and having their grievances redressed satisfactorily.

1. **Genesis of Consumer Protection Laws**

The need to ensure the basic rights to health, safety, etc. of consumers has long been recognised the worldover and various general legislations were enacted in India and abroad in this direction. In India, the general enactments other than the law of torts which ultimately aimed at protection of consumers interests are the Indian Contract Act, 1872, the Sale of Goods Act, 1930, the Dangerous Drugs Act, 1930, the Agricultural Produce (Grading and Marketing) Act, 1937, the Drugs and Cosmetics Act, 1940, the Indian Standards Institution (Certification Marks) Act, 1952, the Prevention of Food Adulteration Act, 1954, the Drugs and Magic Remedies (Objectionable Advertisements) Act, 1954, the Essential Commodities Act, 1955, the Standards of Weights and Measures Act, 1976 (Now Legal Metrology Act, 2009), the Trade and Merchandise Marks Act, 1958, (Now Trade Marks Act, 1999), the Patents Act, 1970, the Hire Purchases Act, 1972 and the Prevention of Black Marketing and Maintenance of Supplies of Essential Commodities Act, 1980.

These legislations contained regulatory provisions and contravention of these provisions attracted civil liability. This meant that an ordinary consumer had no other remedy but to initiate action by way of a civil suit which involved lengthy legal process proving to be too expensive and time consuming for lay consumers. In fact, at times, the time and cost involved in the legal process was disproportionate to the compensation claimed and granted to an individual consumer. Though the MRTP Commission proved to be far more accessible and less time-consuming than the Civil Courts, its single central location at New Delhi did not make the redressal agency accessible to all consumers, especially those located in the remote towns and villages of the country. Therefore, it became necessary to evolve laws directed at protecting the consumers and at the same time, providing for remedies which are simpler, more accessible, quicker and less expensive. This paved the way for enactment of the Consumer Protection Act in 1986 providing for simple, quick and easy remedy to consumers under a three-tier quasi-judicial redressal agency at the District, State and National levels. To make the Act more effective and meaningful, necessary changes have been brought by Consumer Protection (Amendment) Act, 2002, which came into force w.e.f. March 15, 2003.

This is based on the basic rights of consumers as defined by the International Organisation of Consumers (IOCU) viz., the Rights to Safety, to Information, of Choice, to be Heard, to Redressal, to Consumer Education, to Healthy Environment and to Basic Needs.

Scope of the Act

The Act extends to the whole of India except the State of Jammu and Kashmir and applies to all goods and services unless otherwise notified by the Central Government. The Act received the Presidents assent on 24.12.1986. However, all provisions of the Act except those relating to establishment, composition, jurisdiction, etc. of the Consumer Disputes Agencies (which came into force on 1.7.1987) came into force on 15.4.1987.

2. **Definitions**

Section 2(1) of the Act defines various terms used in the Act. Some of the definitions are given hereunder: Complainant means (i) a consumer, or (ii) any voluntary consumer association registered under the Companies Act, 1956, or under any other law for the time being in force; or (iii) the Central Government or any State Government, who or which makes a complaint; or (iv) one or more consumers where there are numerous consumers having the same interest; (v) in case of death of a consumer, his legal heir or representative; who or which makes a complaint [Section 2(1)(b)]

An association of persons, to have locus standi as consumer, it is necessary that all the individual persons forming the association must be consumers under Section 2(1)(d) of the Act having purchased the same goods/hired the same service from the same party i.e. they should have a common cause of action. Thus, unlike MRTP Act, 1969, the Redressal Machinery under Consumer Protection Act, 1986 has no power to initiate cases suo-moto. Complaint means any allegation in writing made, with a view to obtaining any relief, by a complainant that (i) an unfair trade practice or a restrictive trade practice has been adopted by any trader or service provider; (ii) the goods bought by him or agreed to be bought by him suffer from one or more defects; (iii) the services hired or availed of or agreed to be hired or availed of by him suffer from deficiency in any respect; (iv) a trader or the service provider, as the case may be, has charged for the goods or for the services mentioned in the complaint, a price in excess of the price— — fixed by or under any law for the time being in force; — displayed on the goods or any package containing such goods; — displayed on the price list exhibited by him by or under any law for the time being in force — agreed between the parties. (v) goods which will be hazardous to life and safety when used are being offered for sale to the public,— — in contravention of any standards relating to safety of such goods as required to be complied with, by or under any law for the time being in force; — if the trader could have known with due diligence that the goods so offered are unsafe to the public.

(vi) services which are hazardous or likely to be hazardous to life and safety of the public when used, are being offered by the service provider which such person could have known with due diligence to be injurious to life and safety. [Section 2(1)(c)].

14.5.2. International Organisations and Agreements in the Area of Food Standards, Quality, Research and Trade

In many countries, local authorities are assigned responsibility for human health protection, on the assumption that they are best able to address local problems through locally tailored solutions. Indeed, the regulation of food control, food safety and food trade generally takes place at national and subnational levels. Nonetheless, at the outset of the 21st century it is impossible to ignore the international context in which national regulation takes place, as international issues have grown in prominence and influence in recent years. This is both because of the extraordinary interdependence of nations in the trade arena, as well as the growing recognition on the part of national governments of the need or the obligation to base their own standards on those prepared under the auspices of international organizations. Efforts to find solutions to the questions of global food insecurity and to provide substance to concepts such as the right to adequate food have also bolstered interest in collaboration in the international arena. A plethora of governmental, intergovernmental and nongovernmental organizations (NGOs) are active to varying degrees in the formulation of food standards and the search for solutions to global food problems. United Nations (UN) agencies, UN common system organizations, NGOs, advocacy groups and treaty bodies devote their resources and expertise to one or more of the issues exercising governments and industries with respect to food control, food safety and food trade. Accordingly, this chapter turns to the twin issues of international standard-setting and international guidance, examining some of the most influential international and regional organizations which either serve as the fora for governments and other parties to discuss and resolve food-related concerns or which produce and disseminate guidelines or other forms of advice.

14.5.3. World Trade Organization (WTO)

From 1948 to 1994, successive rounds of multilateral negotiation under the General Agreement on Tariffs and Trade (GATT) established the governing international rules for trade between states. Whereas the first negotiations focused on lowering tariffs on imported goods, later negotiations also covered non-tariff barriers. The latest and largest negotiation round was the Uruguay Round of Multilateral Trade Negotiations from 1986 to 1994, which led to the creation of the World Trade Organization (WTO) on 1 January 1995. The Uruguay Round included not only goods but also services and intellectual property, and for the first time brought agricultural products under the discipline of international trade rules.

The WTO, located in Geneva, Switzerland, was established as the international body to deal with rules of the multilateral trade system among states. Its objectives are to help trade flow as freely as possible, to further liberalize trade through negotiation and to set up an impartial means of settling disputes. Currently, the WTO membership includes 147 member states and one regional economic integration organization, while many

other countries are negotiating membership. These latter, as well as a number of international organizations, have observer status at the WTO. Major decisions are made by the entire membership and are normally achieved through consensus: although a majority vote is possible, to date it has never been used.

The highest decisionmaking body is the Ministerial Conference, which meets at least once every two years. More routine work is supervised by the General Council, which consists of the special ambassadors or heads of delegations of countries having diplomatic missions in Geneva, and which meets several times per year. The General Council also meets as the Dispute Settlement Body to oversee procedures for settling disputes, and meets as the Trade Policy Review Body to analyse members' trade policies. Numerous other specialized councils, committees, working parties and negotiating groups deal with a wide range of issues and areas. The WTO Secretariat, headed by a Director General, provides administrative and technical support, carries out trade policy analyses, assists in the resolution of trade disputes and addresses accession negotiations for new members.

1. **Functions**

At the heart of the WTO are trade agreements, ministerial decisions and declarations that provide the legal ground rules for international commerce. All WTO members have signed and ratified the agreements in their parliaments or legislatures, and all are bound by the agreements' provisions and requirements. Foremost is the Marrakesh Agreement Establishing the World Trade Organization, which serves as an umbrella agreement, and annexed to it are various agreements on trade in goods and services, traderelated aspects of intellectual property rights, dispute settlement, trade policy reviews, some plurilateral agreements and a number of ministerial declarations and decisions. Currently, there are about 60 such agreements, declarations and decisions in place.

14.5.4. Codex Alimentarius

During the early 20th century, many individual countries set about developing food laws and standards according to their own circumstances and needs. At the same time, rapid progress was being made in food science and technology, and more information about food and food-related matters was becoming available to the public. But whereas previously consumers' concerns had extended only as far as the "visibles" – weights and measures, size variations, misleading labelling and poor quality – concerns now included a fear of the "invisibles", i.e. health risks that could not be seen, smelled or tasted, such as micro-organisms, pesticide residues and environmental contaminants.

Codex operates based on its Procedural Manual, which consists of the Codex Statutes and Rules of Procedure which together outline Codex's membership, the appointment and responsibilities of officers, the frequency and operation of Codex sessions, the voting

procedures (including observer status) and the preparation of records, reports and budget allocations. The Codex Alimentarius Commission meets in principle every two years in plenary session, alternately at FAO headquarters in Rome and WHO headquarters in Geneva, although it may meet more frequently when the need arises. Membership is open to all members of FAO or WHO, and currently includes 171 countries and one regional economic integration organization.

Members are represented by delegations led by senior officials appointed by their governments, and each member state has one vote. Countries which are not yet members may attend meetings of Codex and its subsidiary bodies as observers, and representatives of industry, consumer associations and international academic institutes granted observer status may also participate, although no observers may vote. According to the Rules of Procedure, decisions should be taken by a majority of the votes cast, although in practice most standards, guidelines and codes of practice are adopted by consensus. An Executive Committee acts on behalf of the Codex Commission between its sessions, generally meeting once per year as well as once before each Commission session. It consists of the Chair of the Commission, three ViceChairs, Coordinators (if any) appointed by the Commission for certain regions or groups of countries plus seven further members, one each from the following areas: Africa; Asia; Europe; Near East; North America; SouthWest Pacific; and Latin America and the Caribbean. The Executive Committee may make proposals to the Commission regarding the general orientation, strategic planning and work plan of the Commission, and may also assist in the management of the Commission's standards development programme. The Executive Committee may establish such sub-committees from among its members as it may deem necessary to enable it to exercise its functions as effectively as possible. The Codex secretariat is based at FAO headquarters in Rome and is responsible for providing administrative support, organizing the sessions and coordinating the work of Codex's subsidiary bodies. Six Codex Coordinating Committees act in an advisory capacity, working toward making Codex responsive to regional interests and the concerns of developing countries.

1. **Functions**

More than forty years after its creation, the Codex Alimentarius (Latin for "food code") has become the authoritative collection of internationally adopted food standards covering all the principal foods traded internationally, whether processed, semi-processed or raw. The Codex Alimentarius is also supplemented by the many maximum residue limits established for pesticides in foods and animal feeds, residue levels for veterinary drugs in foods of animal origin and acceptable levels of food additives and contaminants. The preparation of draft food standards and related texts, whether they be intended for worldwide use, for a given region or for a select group of countries, takes place in Codex committees. Membership in these committees is open to all Codex member states, and international organizations may attend as observers committee sessions that are of interest to them. Generally, committees are financially maintained and hosted by member states. The two types of Codex

committees are Commodity Committees and General Subject Committees. Codex Commodity Committees are often referred to as vertical committees because they develop standards that apply to aspects of specific foods or classes of food. Such standards generally concern quality factors such as the composition or presentation of certain products. The Codex Commodity Committee subject matters range from fresh fruits and vegetables to processed meat and poultry products. Currently, eleven such committees are active or in recess. See Box 3. Some of these committees have completed their work and have ceased operation for an unspecified period of time until there is the need to call them back into service, while still others have remained active for the purpose of reviewing standards in order to bring them in line with current practice.

14.5.5. International Organization for Standardization (ISO)

In 1946, 25 countries met to create an international organization to "facilitate the international coordination and unification of industrial standards", which led to the establishment of the International Organization for Standardization (ISO). The ISO is a nongovernmental organization whose membership is currently made up of the national standards institutes of 150 countries, overseen by a central secretariat in Geneva. In some cases the member institutes are governmental while in others they are entirely private industry initiatives. Membership of the ISO works on the basis of one member per country, whichever national standards institute or similar organization is the most representative of standardization in the member state. There are three levels of membership within the ISO. Full members, known as "member bodies", each have one vote, whatever the size or strength of the economy of the country concerned. Member bodies can exercise full voting rights in any policy or technical committee of the ISO. In addition, ISO has two categories of membership for countries with fewer resources which therefore pay reduced membership fees. Although such members do not have a vote, they participate in order to remain up to date on standardization developments.

The first category, "correspondent members", are usually organizations in countries which do not yet have a fully developed national standards system. Such members do not take an active part in the technical work, but are entitled to be kept fully informed about the work of interest to them. The second category, "subscriber members", is institutes from countries with very small economies that nevertheless wish to maintain contact with international standardization. Such members have full access to information about the international standardization process, which assists them in learning about the standards that their products will need to meet on the export market. All strategic decisions are referred to the ISO members, which meet in an annual General Assembly. The proposals are developed by the ISO Council, which is drawn from the membership and meets three times per year. Membership of the Council is rotated to ensure that it continues to be representative of the ISO membership as a whole.

Operations of the ISO are managed by a permanent Secretary General who in turn reports to the President, who is elected for two years.

1. **Functions**

The ISO will only begin development of a new standard when there is clearly a market requirement for it. An industry group or other interested party will communicate the perceived need for a new standard to the ISO via one of ISO's members, which then proposes the new work item to the ISO as a whole. If accepted, the proposal is then referred to the relevant technical committee (made up of experts from the relevant industry, business and technical sectors) which will apply its specialized expertise to the development of the standard. The work of the technical committees is guided by three general policy development committees which ensure that the broader interests of conformity assessment, consumer policy and developing country matters are considered alongside the specific technical aspects of standard development.

The technical committee meets to discuss and debate until it has reached a consensus draft, which is then submitted as a draft international standard to the entire ISO membership for comment and voting. This is a five-month vote, during which many members, in formulating their position on the draft standard, employ public review procedures at national level designed to make draft standards known and available to interested parties and the general public at country level and thereafter to take account of any feedback received. Those members which have chosen to be participating members of the technical committee are under an obligation to vote, while all other members are entitled to vote if they so wish. A draft standard is approved if two-thirds of the participating members of the committee vote in favour of the standard and not more than one quarter of all votes cast are negative. The text of the final draft international standard, with eventual modifications, is then submitted again to the entire ISO membership, this time for a two-month vote. However, this vote can only constitute approval or rejection of the standard and may be omitted if the draft international standard received full approval during the first round and the modifications made were minimal. If the result is positive, a new international standard is created.

14.5.6. What is HACCP?

HACCP Stands for Hazard Analysis and Critical Control Point. HACCP is an internationally recognized system for reducing the risk of safety hazards in food.

A HACCP System requires that potential hazards are identified and controlled at specific points in the process. This includes biological, chemical or physical hazards.Any company involved in the manufacturing, processing or handling of food products can use HACCP to minimize or eliminate food safety hazards in their product.

1. **HACCP is based on seven principles:**

I. Conduct a Hazard Analysis

This is where you evaluate your processes and identify where hazards can be introduced. Hazards can be physical (i.e. metal contamination), chemical (i.e. can a cleaning product contaminate the product, are there toxins that could contaminate the product?) or biological (at what points could bacteria or virus contaminate your product?). You will need to make sure that you have the expertise to make an accurate evaluation of the hazards. This means that if you do not have sufficient expertise in your organization you will need to identify external resources that you can use to perform the hazard analysis.
The hazard identification is done in two steps, first the identification of hazards, then an evaluation of the hazard. The hazard evaluation is a determination of the degree of risk to the user from the identified hazard. Once the hazard is identified and evaluated the team must identify critical control points. These are points where the hazard must be controlled or it will present a risk to the end user.

II. Identify the Critical Control Points

At what steps in your process can controls be applied to prevent or eliminate the hazards that have been identified? These are your critical control points. For each critical control point you will identify the preventive measure. How will you prevent the hazard?: Use of specific Temperature, ph, time, procedures? Establish a maximum or minimum limit for temperature, time, pH, salt level, chlorine level or other processing characteristic that will control the hazard. This is the critical limit for the CCP. If this limit is ever exceeded corrective action must be taken, and all affected product controlled.

III. Establish Critical Limits

Your next step is to establish criteria for each critical control point. What criteria must be met to control the hazard at that point? Is it a minimum temperature? Are there regulatory limits that you must meet for this control point?

IV. Establish Monitoring Procedure

What will you measure and how will you measure it? You need to monitor the process at the critical control point and keep records to show that the critical limits have been met. Can you do continuous monitoring of the control point? If not, how often will the measurements need to be performed to show that the process is under control?
The monitoring that takes place at the critical control points is essential to the effectiveness of the HACCP program. The monitoring program will be made up of physical measurement or observations that can be done in a timely manner, to provide the information in a time frame that allows you to take action and control product if an out of control situation occurs.

V. Establish Corrective Actions

You will establish what actions need to be taken if a critical limit is not met. This will be identified ahead of time for each CCP. The action must make sure that no unsafe product is released. There must also be an evaluation of the process to determine the cause of the problem and an elimination of the cause. The action or actions taken have two purposes, to control any nonconforming product resulting from the loss of control, and to identify the cause, eliminate it and prevent the situation from reoccurring. By identifying the corrective action before an out of control situation occurs, you are prepared to take action quickly if and when it does occur.

VI. Establish Record Keeping Procedure

You will determine what records are needed to show that the critical limits have been met, and the system is in control. Address regulatory requirements and include records from the development of the system and the operation of the system.

VII. Establish Verification Procedure

The HACCP plan must be validated. Once the plan is in place, make sure it is effective in preventing the hazards identified. Test the end product, verify that the controls are working as planned. Perform ongoing verification of the system. Are measuring and monitoring equipment in control? What are corrective actions showing? Are records being maintained as required? The Food Safety Management Systems reaches beyond the hazard analysis critical control point and also incorporates management systems principles similar to those found in ISO 9001. You will be building a system to manage quality and continual improvement throughout your organization. It will reach beyond the control systems that we have discussed above and into how you plan and manage quality into your organization.

- Global market place
- Increasing incidents of food-borne pathogens
- New pathogens emerging
- Need to protect Brands, control risks

Food Safety Management Systems

To protect themselves, multinational food manufacturers, retailers and grocers are asking their suppliers to implement a Food Safety Management System.

The Global Food Safety Initiative, GFSI has benchmarked a number of Food Safety Management Systems Certification programs, all of which are HACCP based.

- SQF
- FSSC 22000
- BRC

- IFS
- Others

Since ancient times, governing authorities the world over, have made attempts to develop and implement food standards in order to protect health of consumers and prevent dishonest practices in sale of food. There have been several international organisations and agreements which have played a role in enhancing food safety, quality and security, facilitating research and trade. The major organisations which are playing a key role are:

1. Codex Alimentarius Commission (CAC)
2. International Organisation for Standardisation
3. World Trade Organisation

1. Codex Alimentarius Commission

CAC is an intergovernmental body formed with the objective of establishing international standards to protect the health of the consumers and facilitate food and agricultural trade. In 2017, the membership of Codex was 187 member countries and one Member Organisation (European Community) respectively. India is a member through the Ministry of Health and Family Welfare. CAC has become the single most important international reference point for developments associated with food standards. The document published by the CAC is Codex Alimentarius which means 'Food Code' and is a collection of internationally adopted Food Standards. The document includes Standards, Codes of Practice, Guidelines and other recommendations in order to protect consumers and ensure fair practices in food trade. Different countries use Codex Standards to develop national standards.

2. International Organisation for Standardisation (ISO)

The International Organisation for Standardisation (ISO) is a worldwide, non-governmental federation of national standards bodies (ISO member bodies). The mission of ISO is to promote the development of standardisation and related activities in the world with a view to facilitate the international exchange of goods and services, and to develop cooperation in the spheres of intellectual, scientific, technological and economic activity. The work done by ISO results in international agreements which are published as International Standards. ISO 9000 is an international reference for quality requirements. It is concerned with "Quality Management" of an organisation. Adoption of these standards is voluntary. The difference between Codex and ISO are given in the box given below:

Differences between Codex and ISO	
Codex	**ISO**
• Used to develop national regulations • Slow to change	• Voluntary • Standards are reviewed every five years.

• Describe the minimal acceptable practices	• Describe current standard industrial practices.

For more information visit http.www.iso.org

3. World Trade Organisation (WTO)

WTO was established in 1995. The main objective of WTO is to help trade flow smoothly, freely, fairly and predictably, by administering trade agreements, settling trade disputes, assisting countries in trade policy issues. The WTO Agreement covers goods, services and intellectual property. In order to enforce adoption and implementation of standards, there is a need for a strong Food Control System. An effective food control system must consist of — (i) Food Inspection and (ii) Analytical capability.

Food Inspection: Conformity of products to standards is verified through inspection. This will ensure that all foods are produced, handled, processed, stored and distributed in compliance with regulations and legislation. Government / Municipal authorities appoint food inspectors to investigate the status of quality conformity to standards in their laboratories.

Analytical capability: There is need for well-equipped, state-of-the-art accredited laboratories to carry out analysis of food. Further, well- trained personnel having knowledge of principles of laboratory management and physical, chemical and microbiological analysis of food, test foods and food products are also required. A broad range of analytical capabilities is required for detecting food contaminants, environmental chemicals, biotoxins, pathogenic bacteria, food-borne viruses and parasites.

Check your progress - 3
Notes: a) Write your answers in the space given below.
b) Compare your answers with those given at the end of the unit.
5. What is the full form of ISI?
6. What is the scope of consumer protection Act 1986?

5. What is the full form of ISI?

The ISI mark is by far the most recognized certification mark in the Indian subcontinent. The name ISI is an abbreviation of Indian Standards Institute, the former name of the Bureau of Indian Standards.

6. What is the scope of Consumer Protection Act 1986?

The Consumer Protection Act, 1986 was enacted to provide for better protection of the interest of the consumers and for the purpose to make provisions for the establishment of Consumer Councils and other authorities in the settlement of consumer disputes and for matters connected therewith.

14.6. LET US SUM UP

In this unit, defines “food law” to include all legislation that has an impact, directly or indirectly, on food, and accordingly its scope is very wide.
Then we studied about some of the important Bureau of Indian Standards.
We also discussed about PFA, , AGMARK,CCFS,CFL,BIS&FSSAI.
The last part of the unit focused on which examines the myriad factors that determine a country’s legislative priorities and how it will go about addressing these.

14.7. UNIT- END- EXERCISES

1. What are food laws?
2. What is Fssai What are food safety and standards rule?
3. What is food laws and regulations?
4. What is Food Safety Act?
5. What is Food Safety and Standards Act 2006?
6. Explain why food safety and quality are of global concern.
7. Explain the terms: hazard, toxicity, contamination, food quality, adulteration.
8. What is Codex Alimentarius?
9. Discuss the significance of HACCP.
10. List the national and international food standards.
11. What is agmark and ISI?
12. What is the scope of Consumer Protection Act 1986?

14.8. ANSWER TO CHECK YOUR PROGRESS

1. Briefly Explain the HACCP is based on seven principles:

Conduct a Hazard Analysis

This is where you evaluate your processes and identify where hazards can be introduced. Hazards can be physical (i.e. metal contamination), chemical (i.e. can a cleaning product contaminate the product, are there toxins that could contaminate the product?) or biological (at what points could bacteria or virus contaminate your product?). You will need to make sure that you have the expertise to make an accurate evaluation of the hazards. This means that if you do not have sufficient expertise in your organization you will need to identify external resources that you can use to perform the hazard analysis.
The hazard identification is done in two steps, first the identification of hazards, then an evaluation of the hazard. The hazard evaluation is a determination of the degree of risk to the user from the identified hazard. Once the hazard is identified and evaluated the team must identify critical

control points. These are points where the hazard must be controlled or it will present a risk to the end user.

Identify the Critical Control Points

At what steps in your process can controls be applied to prevent or eliminate the hazards that have been identified? These are your critical control points. For each critical control point you will identify the preventive measure. How will you prevent the hazard?: Use of specific Temperature, ph, time, procedures? Establish a maximum or minimum limit for temperature, time, pH, salt level, chlorine level or other processing characteristic that will control the hazard. This is the critical limit for the CCP. If this limit is ever exceeded corrective action must be taken, and all affected product controlled.

Establish Critical Limits: Your next step is to establish criteria for each critical control point. What criteria must be met to control the hazard at that point? Is it a minimum temperature? Are there regulatory limits that you must meet for this control point.

Establish Monitoring Procedure: What will you measure and how will you measure it? You need to monitor the process at the critical control point and keep records to show that the critical limits have been met. Can you do continuous monitoring of the control point? If not, how often will the measurements need to be performed to show that the process is under control?

The monitoring that takes place at the critical control points is essential to the effectiveness of the HACCP program. The monitoring program will be made up of physical measurement or observations that can be done in a timely manner, to provide the information in a time frame that allows you to take action and control product if an out of control situation occurs.

Establish Corrective Actions

You will establish what actions need to be taken if a critical limit is not met. This will be identified ahead of time for each CCP. The action must make sure that no unsafe product is released. There must also be an evaluation of the process to determine the cause of the problem and an elimination of the cause. The action or actions taken have two purposes, to control any nonconforming product resulting from the loss of control, and to identify the cause, eliminate it and prevent the situation from reoccurring. By identifying the corrective action before an out of control situation occurs, you are prepared to take action quickly if and when it does occur.

Establish Record Keeping Procedure

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2. How to get authority to use ISI mark?

For getting an authority/or license to use ISI mark on the products, the manufactures have to apply to BIS for permission. BIS people then send a team to inspect the factory, verify the capabilities of manufacturer to produce and also test the products on continuous basis in accordance with the relevant Indian standards. They also check the quality of the products and other facilities and after satisfying themselves they give permission to use ISI mark. BIS gives a well defined quality control system to the manufactures and tells them to exercise control measures at various stages like,

- Raw material,
- Diff. stages of production,
- Finished product stage.

BIS keeps a supervisory control to ensure that the ISI marks product are always in conformity with the relevant Indian standards. BIS also has an elaborate Quality Audit System under which they draw the samples

- From the factory production line, or
- From factory store , or
- Purchase them from the open market.

And then test the samples in their own labs or recognized labs to check the conformity with the relevant Indian standards. BIS also entertains complaints from consumers and arranges free replacements of defective ISI-marked goods. BIS also provides training in statistical quality control to its applicants and licensees for improving their technical skill.

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